MARINE MAMMAL MONITORING DURING LAMONT-DOHERTY EARTH OBSERVATORY'S SEISMIC PROGRAM OFF THE ALEUTIAN ISLANDS, ALASKA, JULY–AUGUST 2005

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for

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and

National Marine Fisheries Service, Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

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by

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LIST OF ACRONYMS AND ABBREVIATIONS

ADT	Alaska Daylight Time
Bf	Beaufort Wind Force
CBD	Center for Biological Diversity
CFR	(U.S.) Code of Federal Regulations
cm	centimeter
CPA	Closest (Observed) Point of Approach
dB	decibels
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
ADT	Alaska Daylight Time
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
GI	Generator–Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
$g(0)$	probability of seeing a group located directly on a survey line
GPS	Global Positioning System
h	hours
hp	horsepower
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kW	kilowatt
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
µPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
min	minutes
MMO	Marine Mammal (and Sea Turtle) Observer
MMPA	(U.S.) Marine Mammal Protection Act
n	sample size
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
NSF	(U.S.) National Science Foundation

PI	Principal Investigator
pk-pk	peak-to-peak
psi	pounds per square inch
re	in reference to
rms	root-mean-square
rpm	revolutions per minute
s	seconds
scfm	standard cubic feet per minute
SD	Shut down of the GI gun not associated with mitigation
s.d.	standard deviation
SPL	Sound Pressure Level
SZ	Shut down of the GI gun because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, ***excluding*** periods 90 s to 2 h after the GI gun was turned off (post-seismic), nighttime observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force >5 (>2 for cryptic species, including beaked whales and porpoises). Also excluded were periods when the *Thompson*'s speed was <3.7 km/h (2 kt) or with >60º of severe glare between 90º left and 90º right of the bow.

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to Lamont-Doherty Earth Observatory (L-DEO) by the National Marine Fisheries Service (NMFS) on 18 July 2005. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey off the Aleutian Islands, Alaska. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). Cetaceans exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It is not known whether seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals or sea turtles that occur close to the seismic source. Nonetheless, NMFS requires measures to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects. In particular, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals and sea turtles, and to shut down the airguns when mammals or turtles are detected within designated safety radii.

Program Described

The scientific program off the Aleutian Islands consisted of multibeam bathymetric (MBB) sonar surveys, rock dredging, and low-energy marine seismic surveys. The purpose of the study was to collect rock samples for geochemical studies aimed at understanding the genesis of the volcanic rocks and its relationship to subduction-related tectonics. These processes change continuously from east to west along the Aleutian arc. The seismic and rock dredging program took place around the Aleutian Islands between 51º50' and 54º20'N, and between 172ºE and 166ºW (Fig. 1.1). The study was conducted from the R/V *Thomas G. Thompson* in the territorial waters and Exclusive Economic Zone (EEZ) of the U.S.A. Water depths within the study area ranged from 100 to 3500 m. The *Thompson* departed Dutch Harbor, Alaska, on 20 July 2005, and seismic operations commenced on 23 July. The study was concluded on 20 August 2005, when the vessel returned to Dutch Harbor.

This seismic survey used one Generator Injector (GI) gun with a generator volume of 45 in^3. This is a lower discharge volume than the 105 in^3 upon which safety and disturbance radii, as well as "take" estimates, were based. Therefore, estimated radii are ~33% greater than required for the specific GI gun used during the Aleutian Study, and "takes" are correspondingly overestimated. The GI gun was deployed from the *Thompson*, and a 350-m streamer containing hydrophones was towed behind the vessel to receive the returning seismic acoustic signals. The MBB sonar was operated from the *Thompson* throughout the study.

Monitoring and Mitigation Approach and Methods

Three trained marine mammal observers (MMOs) were aboard the *Thompson* throughout the study. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals and sea turtles near the seismic source. ***(B)***

Implement a shut down of the seismic source when marine mammals or turtles were sighted near or within the designated safety radii. ***(C)*** Monitor for marine mammals and sea turtles before commencement of seismic operations.

During daylight hours at least one MMO watched for marine mammals and sea turtles at all times while the GI gun operated and when the vessel was underway but the GI gun was not firing. The MMOs used 7x50 binoculars, one set of 25x150 Big-eye binoculars, and the naked eye to scan the surface of the water around the vessel for marine mammals and turtles. The distance from the observer to the sighting was estimated using reticles on the binoculars. When a marine mammal (or turtle) was detected within or approaching the safety radius, the MMO contacted the gun operators to implement a shut down of the GI gun.

Primary mitigation procedures, as required by the IHA, included the following: ***(A)*** Initial monitoring of the applicable safety radii for 30 min prior to firing of the GI gun; and ***(B)*** immediate shut down of the GI gun whenever marine mammals or turtles were detected within or about to enter the applicable safety radius. The safety radii during the survey were based on the distances within which the received levels of seismic sounds were expected to diminish to 190 or 180 dB re 1 µPa (rms) for pinnipeds, and cetaceans and turtles, respectively. In addition, special precautionary safety radii were required for sea otters and for endangered Steller sea lions and North Pacific right whales.

Monitoring Results

The *Thompson* traveled a total of 9197 km within the study area (Table ES.1; Fig. 1.1). The GI gun operated along ~6% of the total ship track. The actual number of kilometers traveled during seismic periods was much lower (537 km) than anticipated in the IHA Application and Environmental Assessment (4112 km). This reduction in seismic operations was due to the successful use of the MBB sonar to identify dredge targets.

The GI gun was started up on four occasions, and the MMOs were on watch during all four start ups. The GI gun was not started at night, but some seismic operations proceeded into or through the night. Measured in hours, MMOs were on watch for 54% of seismic operations, including all daylight hours with seismic operations; 45% of the seismic operations occurred during daylight. In total, 4854 km of visual observations were made during both seismic and non-seismic periods (Table ES.1).

Analyses of marine mammal behavior and density data focused on sightings and survey effort in the study area during "useable" survey conditions, which represented 35% (in hr) of the total visual effort (Table ES.1). "Useable" effort excluded periods 90 s to 2 h after the GI gun was turned off (post-seismic), poor visibility conditions (<3.5 km), and periods with Beaufort Wind Force (Bf) >5, or Bf >2 for porpoises. Also excluded were periods when the *Thompson's* speed was <3.7 km/h (2 kt) or with >60° of severe glare between 90º left and right of the bow.

Numerous species of cetaceans and pinnipeds, as well as sea otters, are known to occur in the Aleutian Islands. A total of ~381 individual cetaceans were sighted in 144 groups, and 9 pinnipeds were seen in 5 groups (Table ES.1). No injured cetaceans or pinnipeds potentially associated with the operations were sighted at any time during the cruise. No sea turtles or sea otters were seen during the cruise.

In general, poor sighting conditions (i.e., fog) and the limited amount of seismic operations during the study did not allow meaningful interpretation of sighting rates and behavior during seismic vs. non-seismic periods. In fact, observed densities of odontocetes during non-seismic periods were lower than those during seismic periods. Previous surveys have generally shown that apparent densities of marine

mammals are higher during non-seismic than seismic periods. This unexpected result was caused by an encounter with a local concentration of sperm whales during one of the limited seismic periods in the Aleutian study.

Number of Marine Mammals Present and Potentially Affected

During the Aleutian study, the "safety radii" called for by NMFS for most pinnipeds and cetaceans were the best estimates of the 190 and 180 dB re 1 μPa (rms) radii for one GI gun with a volume of 105 in^3. More conservative (larger) radii were required for sea otters and for endangered Steller sea lions and North Pacific right whales. The generator volume of the GI gun actually used during the study was 45 in^3, making the estimated radii ~33% larger than necessary (i.e., precautionary). The GI gun was shut down once during seismic operations due to the presence of a group of seven Dall's porpoises that was about to enter the designated safety zone (Table ES.1). These porpoises were first observed outside the safety radius. Because they were not observed within the safety radius, it is unlikely that they were exposed to sounds with received levels ≥180 dB before mitigation measures were implemented.

Any large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa (rms), and pinnipeds exposed to received levels of ≥170 dB re 1μPa, were assumed to have been potentially disturbed during seismic operations. Based on direct observations, a total of 63 cetaceans in 35 groups were seen within the ≥160 dB radius, and none of these were within the 170 dB radius. No pinnipeds were observed during seismic operations.

Minimum and maximum numbers of marine mammals exposed to ≥160 and ≥170 dB re 1 μPa (rms) were also estimated based on densities of marine mammals derived by line-transect procedures. These estimates allowed for animals not seen by MMOs. A minimum of one individual delphinids or Dall's porpoise might have been in the areas about to be exposed to seismic sounds with received levels ≥170 dB re 1 μPa (rms), based on observations during non-seismic periods. Thus, based on this approach, ~1 delphinid/Dall's porpoise (if it did not swim away from the approaching vessel) might have been exposed to sound levels that could have disturbed it. Similarly, prior to the close approach of the vessel, ~19-103 cetaceans are estimated to have been within the areas about to be exposed to ≥160 dB. These estimates based on actual density data are lower than the "harassment takes" estimated prior to the survey. The maximum estimate of the number of exposures to ≥160 dB (n = 103) is only about 5% of the potential "take" estimated in the IHA Application, and the minimum estimate of ~19 individuals is only about 1% of the estimated take. Few pinnipeds were sighted during the cruise and none were seen during the seismic periods. Therefore, no pinnipeds are estimated to have been exposed to or potentially disturbed by strong seismic sounds.

In summary, the estimated number of cetaceans potentially affected by L-DEO's survey was much lower than that authorized by NMFS, mainly because the amount of seismic operation during the survey was less than anticipated. Given this, and the mitigation measures that were applied, the effects were very likely localized and transient, with no significant impact on either individual cetaceans or their populations. There was no evidence that any pinnipeds, sea otters, or sea turtles were affected.

TABLE ES.1. Summary of *Thompson* operations, observer effort, and marine mammal sightings during the Aleutian cruise, 20 July–20 August 2005.

	Non-Seismic			Seismic			
	Useable[a]	**Other**	**Post Seismic**	**Useable[a]**	**Other**	**Total Useable[a]**	**Total**
Operations in h							
Vessel Nighttime	-	195	2	-	23	-	221
Vessel Daylight	147	349	8	9	11	156	524
Vessel Total	**147**	**544**	**10**	**9**	**35**	**156**	**745**
Observer Nighttime	-	1	-	-	4	-	5
Observer Daylight	105	184	8	9	11	114	317
Observer Total	**105**	**185**	**8**	**9**	**15**	**114**	**322**
Operations in km							
Vessel Nighttime	-	3323	28	-	294	-	3645
Vessel Daylight	2711	2498	99	116	127	2827	5551
Vessel Total	**2711**	**5820**	**128**	**116**	**421**	**2827**	**9197**
Observer Nighttime	-	10	-	-	42	-	52
Observer Daylight	2030	2435	99	110	127	2140	4802
Observer Total	**2030**	**2445**	**99**	**110**	**169**	**2140**	**4854**
No. Cetacean Sightings (Indiv.)	67 (169)	40 (139)	2 (10)	32 (52)	3 (11)	99 (221)	144 (381)
No. Pinniped Sightings (Indiv.)	2 (3)	3 (6)	-	-	-	2 (3)	5 (9)
No. Shut Downs (SZ)	-	-	-	-	1 (7)	-	1 (7)

[a] See *Acronyms and Abbreviations* for the definition of "useable" effort.

1. INTRODUCTION

Lamont-Doherty Earth Observatory (L-DEO) conducted a rock dredging and marine seismic study from 20 July to 20 August 2005 off the Aleutian Islands, Alaska (Fig. 1.1). The project was conducted aboard the R/V *Thomas G. Thompson*, which is owned by the U.S. Navy and operated by the University of Washington. The study used a small source of seismic energy consisting of one GI gun with generator volume 45 in^3.

The purpose of the study was to collect rock samples for geochemical studies aimed at understanding the genesis of the volcanic rocks and its relationship to subduction-related tectonics. These processes change continuously from east-to west along the Aleutian arc

Seismic operations with the single GI gun were planned in order to determine the composition of the ocean floor, which would help in locating suitable locations for rock dredging. However, because data acquisition from the multibeam bathymetric (MBB) sonar was successful at locating dredge targets, seismic operations were limited during the study.

The study was under the direction of the Principal Investigators (PIs) Dr. Gene Yogodzinski of the University of South Carolina, Dr. Peter Kelemen of L-DEO, Dr. H. Gary Greene of Moss Landing Marine Laboratories, and Dr. Brad Singer of the University of Wisconsin. Dr. David Scholl of Moss Landing was an Associate PI. The vessel was self-contained, and the crew lived aboard the vessel for the entire cruise.

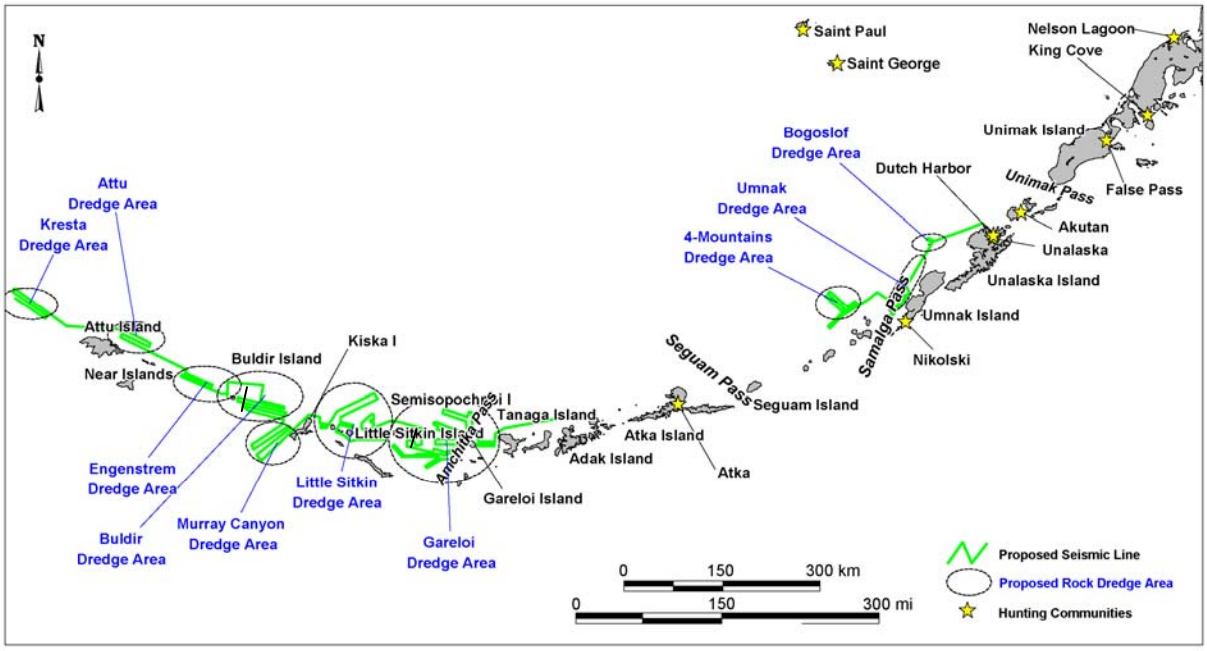

FIGURE 1.1. The Aleutian study area, showing locations where seismic survey operations and rock dredging were contemplated during the planning phase. (See Figure 2.1, later, for actual locations of seismic operations.)

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004). The

effects could consist of behavioral or distributional changes, and perhaps (for animals close to the sound source) temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur) auditory effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species (ESA) Act, at least if the effects are considered to be "biologically significant".

Numerous species of cetaceans and pinnipeds inhabit the area around the Aleutian Islands. Several of the species are listed as "Endangered" under the U.S. Endangered Species Act (ESA), including the humpback, sei, fin, blue, North Pacific right, and sperm whales. Other species of special concern that are known to occur in the area include the Steller sea lion, for which the western stock is listed as "Endangered" and the eastern stock is listed as "Threatened", the sea otter, and the leatherback turtle, which is listed as "Endangered". Unlike other marine mammals, which are managed by NMFS, the sea otter is managed by the U.S. Fish and Wildlife Service (USFWS).

On 20 Dec. 2004, L-DEO requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the seismic operations off the Aleutian Islands, Alaska (LGL Ltd. 2004a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also written to evaluate the potential impacts of the marine seismic survey near the Aleutian Islands (LGL Ltd. 2004b). The EA was adopted by NSF, the federal agency sponsoring this seismic survey. In February 2005, L-DEO and NSF provided updated information about the planned cruise to NMFS; between December 2004 and February 2005, there had been a change of plans regarding the vessel to be used for the cruise, and the specific planned dates. The IHA was issued by NMFS on 18 July 2005 (Appendix A).

The IHA authorized "potential take by harassment" of marine mammals during the seismic cruise described in this report. The ship left Dutch Harbor on 20 July, and returned there 20 August. The first and last days of seismic operations were 23 July and 7 August.

This document serves to meet reporting requirements specified in the IHA. The primary purpose of this report is to describe the seismic survey near the Aleutian Islands, to describe the associated marine mammal (and sea turtle) monitoring and mitigation program and results, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries. During this project, sounds were generated by one GI gun used during seismic operations, two different multibeam bathymetric (MBB) sonars, an echosounder, a 12-kHz pinger, and general vessel operations. No serious injuries or deaths of marine mammals (or sea turtles) were anticipated from the seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Appendix B provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2005b), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB

re 1 μPa (rms)[1] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels are unlikely to injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize the numbers of cetaceans and pinnipeds exposed to sound levels exceeding 180 and 190 dB (rms), respectively. In addition, for this project NMFS specified a safety (shut down) criterion of 180 dB for sea turtles and special safety requirements for Steller sea lions, North Pacific right whales, and sea otters.

Disturbance to marine mammals could occur at distances beyond the safety (shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airgun or perhaps sonar (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) are likely to be disturbed appreciably. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins and pinnipeds are generally less responsive (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of behavioral disturbance for those groups (LGL Ltd. 2004a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time, its distance from the sound source, and the received level of the sound and the associated water depth. Some individuals respond behaviorally at received levels somewhat below the nominal 160 or 170 dB (rms) criteria, but others tolerate levels somewhat above 160 or 170 dB without reacting in any substantial manner.

A notice regarding the proposed issuance of an IHA for the survey off the Aleutian Islands was published by NMFS in the *Federal Register* on 21 March 2005 and public comments were invited (NMFS 2005a). The Animal Welfare Institute, the Center for Biological Diversity (CBD), and an individual submitted comments (NMFS 2005b).

On 18 July 2005, L-DEO received the IHA that had been requested for the Aleutian project, and on 4 Aug 2005 NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2005b). The second notice responded to comments received by NMFS, and provided additional information concerning the IHA and any changes from the originally proposed IHA. A copy of the issued IHA is included in this report as Appendix A.

The IHA was granted to L-DEO on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed, and
- the agreed upon monitoring and mitigation measures would be implemented.

[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in L-DEO's IHA Application (LGL Ltd. 2004a) and in the IHA issued by NMFS to L-DEO (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2005a,b).

The main purpose of the mitigation program was to avoid or minimize potential effects of L-DEO's seismic survey on marine mammals and sea turtles. This required that observers detect marine mammals and sea turtles within or about to enter the safety radius, and in such cases initiate a shut down of the GI gun. An additional mitigation objective was to detect marine mammals or sea turtles within or near the safety radii prior to starting the GI gun. The start of the GI gun was to be delayed until the safety radii were free of marine mammals or sea turtles (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

1. Provide real-time sighting data needed to implement the mitigation requirements.
2. Estimate the numbers of marine mammals potentially exposed to strong seismic pulses.
3. Determine the reactions (if any) of potentially exposed marine mammals and sea turtles.

Specific mitigation and monitoring objectives identified in the IHA are shown in Appendix A. Mitigation and monitoring measures implemented during the Aleutian cruise are described in detail in Chapter 3.

Report Organization

The primary purpose of this report is to describe the 2005 Aleutian study that was conducted off the Aleutian Islands, including the associated monitoring and mitigation program, and to present results as required by the IHA (see Appendix A). This report includes four chapters:

1. Background and introduction (this chapter);
2. Description of the seismic study;
3. Description of the marine mammal and sea turtle monitoring and mitigation requirements and methods, including safety radii;
4. Results of the marine mammal monitoring program, including estimated numbers of marine mammals potentially "taken by harassment".

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are seven Appendices. Details of procedures that are relatively consistent across L-DEO's recent seismic surveys are provided in the Appendices and are only summarized in the main body of this report. The Appendices include

A. a copy of the IHA issued to L-DEO for this study;

B. background on development and implementation of safety and disturbance radii;

C. characteristics of the *Thompson*, the GI gun, and the sonars;

D. details on visual monitoring, mitigation, and data analysis methods;

E. conservation status and densities of marine mammals in the project region;

F. monitoring effort and list of marine mammals seen during this cruise separated into categories based upon seismic activity, water depth, and Beaufort wind force;

G. additional supporting details regarding numbers of marine mammals exposed to seismic sounds.

2. ALEUTIAN STUDY DESCRIBED

Procedures used to obtain seismic data during the Aleutian study were similar to those used during previous seismic surveys by L-DEO, e.g., in the Northwest Atlantic (Haley and Koski 2004), in the Gulf of Alaska (MacLean and Koski 2005), and in the Eastern Tropical Pacific off of Central America (Holst et al. 2005a). The Aleutian study used conventional seismic reflection techniques to characterize the earth's crust, including a single towed GI gun as the energy source, and a towed hydrophone streamer (~350 m) as the receiver system. The primary mission of the cruise, however, was not to collect seismic data, but to identify and then dredge for young volcanic rock on the ocean bottom. Throughout most of the cruise, the MBB sonar provided enough information such that the seismic equipment was not needed. Dredging operations were largely successful with ~89 attempts made of which ~75% collected rock from the ocean bottom.

The following sections briefly describe the Aleutian study including the equipment used and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA (Appendix A). More detailed information on the *Thompson* and the equipment is provided in Appendix C.

Operating Areas, Dates, and Navigation

The Aleutian study occurred around the Aleutian Islands between 51º50' and 54º20'N, and between 172ºE and 166ºW (Fig. 1.1). Water depth within the seismic survey area ranged from 100 to 3500 m, and the entire study was conducted in the Exclusive Economic Zone (EEZ) of the U.S.A. The *Thompson* departed Dutch Harbor, Alaska, on 20 July 2005 and arrived off the coast of Attu Island on 22 July. Seismic operations commenced in this area on 23 July and occurred intermittently on ~4 days. The last seismic operations were conducted on 7 August 2005. Seismic operations occurred during both daylight and nighttime periods. The *Thompson* arrived back in Dutch Harbor on 20 August 2005. A chronology of the study is presented in Table 2.1. A summary of the total distances traveled by the *Thompson* during the Aleutian study, distinguishing periods with and without seismic operations, is presented in Table ES.1.

Throughout the study, position and speed of the *Thompson,* and water depth, were logged digitally every 5 s. The marine mammal observers (MMO) also recorded the ship's activities while on duty.

GI Gun Characteristics

A single GI gun with a generator volume of 45 in^3, along with a hydrophone streamer, were towed by the *Thompson* along survey lines in the study area (Fig. 2.1). Safety and disturbance radii for this study were those appropriate for a 105 in^3 GI gun, and were therefore ~33% larger than the radii required for the lower-volume GI gun actually used.

Compressed air supplied by compressors aboard the source vessel powered the GI gun. Seismic pulses were emitted at intervals of ~8 s while the *Thompson* traveled at an average speed of ~11 km/h (6 kt). The 8-s spacing corresponded to a shot interval of ~24 m. During operations, the GI gun was suspended from an air-filled float and was positioned 3 m below the water surface (see Appendix C).

The nominal source level for downward propagation of low-frequency energy of the GI gun is shown in Table 2.2. The nominal source level would be somewhat higher if the small amount of energy at higher frequencies were considered. The source level on the rms basis used elsewhere in this report would be lower, but source levels of GI guns are not normally determined on an rms basis by airgun manufacturers or geophysicists.

TABLE 2.1. Chronology in Greenwich Mean Time (GMT) of events during the July–August 2005 study off the Aleutian Islands, Alaska. Marine mammal observations were conducted during all daylight hours when the vessel was underway, including days when seismic operations were not conducted.

Date (2005)	Time	Event Description
19 Jul		*Thompson* was scheduled to leave Dutch Harbor, Alaska, but departure was delayed; had to wait for new Captain
20 Jul		Departed Dutch Harbor, transit to study area
21 Jul		Transit to study area
22 Jul		Arrived near Attu I., began bathymetric sonar survey
23 Jul	08:58	Seismic operations near Attu I. commenced
23 Jul	18:30	Ceased seismic operations near Attu I.; commenced dredging operations
24 Jul		No seismic operations; sonar surveys and dredging
25 Jul		No seismic operations; sonar surveys and dredging
25 Jul	23:56	Commenced seismic operations near Buldir Island
26 Jul	17:05	Ceased seismic operations; commenced dredging operations
27 Jul		No seismic operations; sonar surveys and dredging
28 Jul		No seismic operations; sonar surveys and dredging
29 Jul		No seismic operations; sonar surveys and dredging
30 Jul		No seismic operations; sonar surveys and dredging
31 Jul		No seismic operations; sonar surveys and dredging
1 Aug		No seismic operations; sonar surveys and dredging
2 Aug		No seismic operations; sonar surveys and dredging
3 Aug		No seismic operations; sonar surveys and dredging
4 Aug		No seismic operations; sonar surveys and dredging
4Aug	22:58	Commenced seismic operations near Kiska Island
5 Aug	11:48	Ceased seismic operations near Kiska Island due to the approach of Dall's porpoises to the safety radius; commenced dredging operations
6 Aug		No seismic operations; sonar surveys and dredging
7 Aug	05:45	Commenced seismic operations near Little Sitkin Island
7 Aug	16:47	Ceased seismic operations off Little Sitkin Island; commenced dredging operations
8 Aug		No seismic operations; sonar surveys and dredging
9 Aug		No seismic operations; sonar surveys and dredging
10 Aug		No seismic operations; sonar surveys and dredging
11 Aug		No seismic operations; sonar surveys and dredging
12 Aug		No seismic operations; sonar surveys and dredging
13 Aug		No seismic operations; sonar surveys and dredging
14 Aug		No seismic operations; sonar surveys and dredging
15 Aug		No seismic operations; sonar surveys and dredging
16 Aug		No seismic operations; sonar surveys and dredging
17 Aug		No seismic operations; sonar surveys and dredging
18 Aug		No seismic operations; sonar surveys and dredging
19 Aug		No seismic operations; sonar surveys and dredging
20 Aug		No seismic operations; sonar surveys and dredging
20 Aug	19:10	Arrived in Dutch Harbor

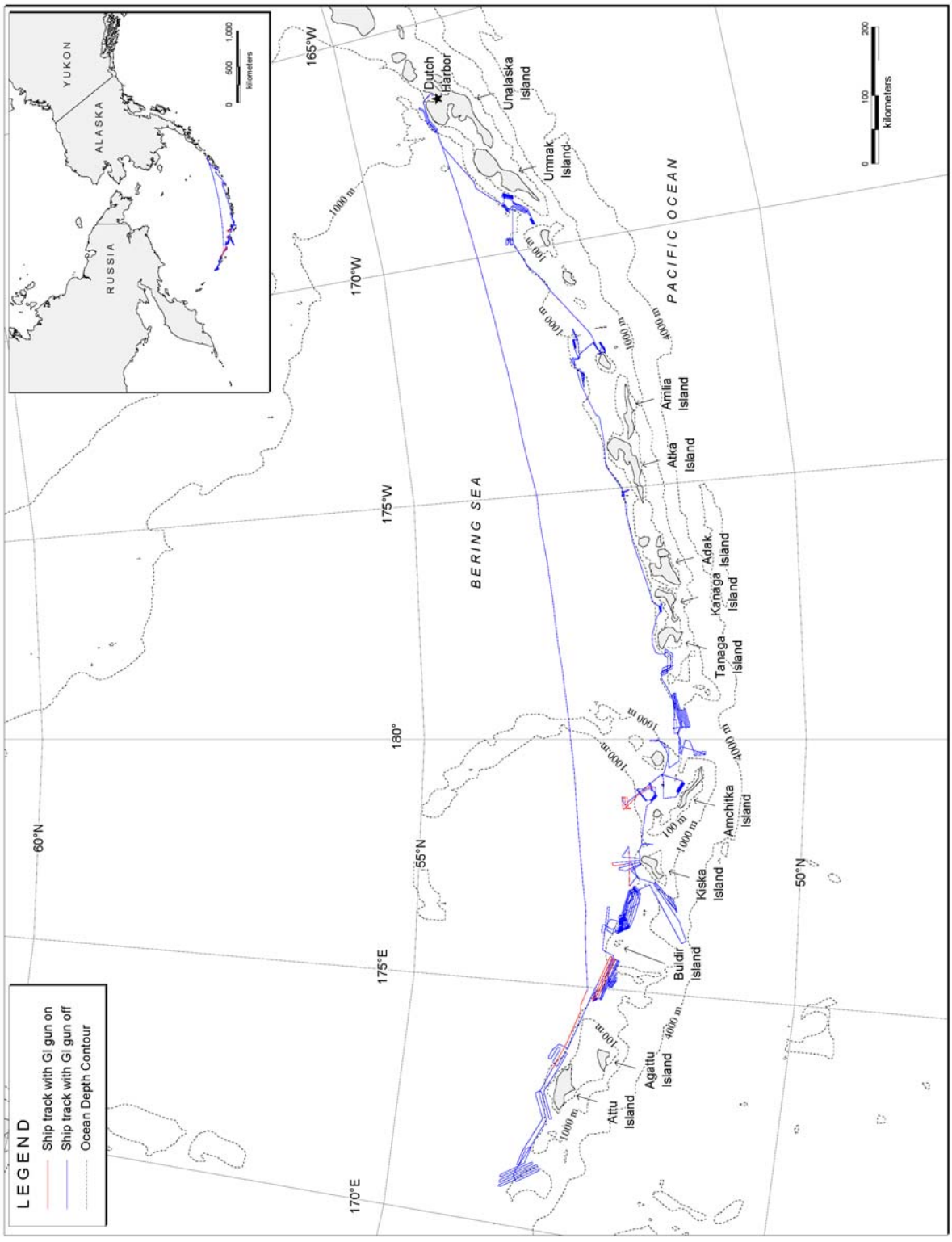

FIGURE 2.1. The Aleutian study area, *Thompson* ship tracks, and locations of seismic survey lines during L-DEO's survey off the Aleutian Islands, Alaska, 20 July – 20 August 2005.

TABLE 2.2. Specifications of the GI gun used during L-DEO's Aleutian study, 20 July–20 August 2005.

Energy source	One 2000 psi GI gun with generator volume 45 in^3
Source output (downward) [a]	0-pk is ~2.7 bar-m (229 dB re 1 µPa-m); pk-pk is ~5.3 bar-m (234 dB)
Towing depth of energy source	3 m
Total air discharge volume (generator)	45 in^3
Dominant frequency components	0–188 Hz

[a] Source level estimates are based on a filter bandwidth of ~0–250 Hz

Other Types of Seismic Operations

During the Aleutian cruise, the GI gun operated during certain other periods besides those in which seismic data were being recorded. Under conditions of poor sightability, the GI gun was operated during transits from waters outside critical habitat for Steller sea lions to the starting points of seismic lines within the designated critical habitat. These transits with the GI gun operating were necessary because the IHA prohibited startup of the GI gun within critical habitat when poor visibility and/or high sea states limited the ability of the MMOs to monitor the full 750-m safety radius applicable in those areas (see Chapter 3 and Appendix A). Outside sea lion critical habitat, the (smaller) designated safety radii for all animals could be monitored during for the 30 min observation period prior to start up of the GI gun.

Multibeam Bathymetric Sonars, Echosounders, and Pinger

Along with the GI gun operations, four additional acoustic systems operated during the cruise. A 30-kHz MBB sonar (Simrad EM300) operated throughout most of the cruise to map the bathymetry and identify dredge targets. A 15.5-kHz Hydrosweep MBB sonar (Krupp-Atlas Elektroniks Hydrosweep DS) was used only once during surveys in very deep waters over Murray Canyon southwest of Kiska Island. The navigational echosounder or fathometer (Abyss Technologies Inc., Model IES-10) was also used only once while conducting bathymetric surveys in very shallow waters just east of Seguam Island. This type of sonar is routinely employed by sea-going vessels to monitor water depths. The 12-kHz pinger was used during most dredge operations over 750 m in depth (~50 dredges). During seismic operations, the 30-kHz echosounder was the only device operated simultaneously with the GI gun. The various sonars are described in further detail in Appendix C.

Rock Dredging

Appropriate dredge sites were located using the MBB sonar. Approximately 89 dredges were conducted during the study, of which ~75% were successful (i.e., rocks were obtained). Dredging operations typically took place in waters 400–1800 m deep. Dredging occurred on hard, rocky substrate provided by young volcanic features that varied from kilometer-scale isolated cones to small extrusions erupted along fault planes cutting structurally complex sea floors. The dredges had a swath width of 1 m, and were a few tens of meters long. While on station for dredging in deeper waters, a 12 kHz pinger was used to monitor the depth of the dredge relative to the sea floor.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal monitoring and mitigation measures implemented for L-DEO's Aleutian study, addressing the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals and sea turtles. The acoustic measurements and modeling results used to identify the safety radii for marine mammals and turtles are then described, followed by a summary of the mitigation measures required by NMFS. The chapter ends with a description of the monitoring methods implemented for this cruise from aboard the *Thompson*, and a description of data analysis methods.

Monitoring Tasks

The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHA issued to L-DEO by NMFS were satisfied, effects on marine mammals and sea turtles were minimized, and residual effects on animals were documented. The objectives of the monitoring program were listed in Chapter 1, *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Thompson* source vessel throughout the Aleutian survey.
- Visually monitor the occurrence and behavior of marine mammals and sea turtles near the vessel whether the GI gun was operating or not.
- Record (insofar as possible) the effects of the GI gun operations and the resulting sounds on marine mammals and turtles.
- Use the monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to strong GI gun sounds.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2005b), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 µPa (rms) for cetaceans and ≥190 dB re 1 µPa (rms) for pinnipeds. These safety criteria are based on an assumption that seismic pulses received at lower levels are unlikely to injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (dolphins, pinnipeds), disturbance is unlikely to occur unless received levels are higher, perhaps ≥170 dB rms for an average animal (see Chapter 1).

Radii within which received levels were expected to diminish to the various relevant values (i.e., 190, 180, 170 and 160 dB re 1 µPa rms) were estimated by L-DEO (Table 3.1). This was done based on a combination of acoustic modeling, as summarized by LGL Ltd. (2004a,b) and in Appendix B, along with empirical measurements of sounds from several airgun configurations (Tolstoy et al. 2004a,b). The acoustic modeling procedure did not allow for bottom reflections. Thus, it was directly applicable to close ranges and, for deep water, somewhat longer ranges, but not to ranges where received levels would be significantly affected by bottom reflections. The results from the empirical study were also limited in various ways. However, the empirical data did show that (as expected) water depth can affect the distance at which received levels would exceed any specific level such as 180 or 170 dB re 1 µPa (rms). Therefore, L-DEO recognizes three strata of water depth for seismic cruises: deep (>1000 m), intermed-

TABLE 3.1. Estimated distances to which sound levels ≥190, 180, 170 and 160 dB re 1 µPa (rms) might be received from the GI gun during the Aleutian seismic survey, July–August 2005. Distance estimates are given for operations in intermediate (100–1000 m) and deep (>1000 m) water, which are the depth strata where seismic operations occurred during this cruise. See Appendix B regarding derivation of these estimates. Safety radii implemented during the study are shown in bold.

Water depth	Estimated Distances at Received Levels (m)[a]			
	190 dB	180 dB	170 dB	160 dB
>1000 m	**10**	**27**	90	275
100–1000 m	**15**	**41**	135	413

[a] Distances were estimated for a 105 in^3 GI gun. The GI gun actually used during the Aleutian study had generator volume 45 in^3. Therefore, these estimated distances are ~33% larger than necessary for the lower-volume GI gun actually used.

iate (100–1000 m), and shallow (<100 m), with associated differences in 160–190 dB radii (see Smultea et al. 2004, 2005; Holst et al. 2005a,b; MacLean and Koski 2005). The Aleutian survey operations were conducted in water >100 m deep, so only intermediate and deep water radii were relevant.

Mitigation Measures as Implemented

The primary mitigation measure that was implemented during the Aleutian cruise was a shut down of the GI gun. This measure is a standard procedure employed during L-DEO seismic cruises and is described in detail in Appendix D. Mitigation also included those measures specifically identified in the IHA (Appendix A) as indicated below.

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

1. Safety radii implemented for the Aleutian cruise were specific for intermediate and deep water depths based on modeling and the acoustic calibration study conducted from the *Ewing* in the Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b), as noted above and described in Appendix B.
2. Shut-down procedures were implemented when a marine mammal was sighted within or approaching the applicable safety radius while the GI gun was operating.
3. A change in vessel course and/or speed was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius.
4. In order for seismic operations to start up during day or night, the full applicable safety radius must have been visible for at least 30 min.

Special Mitigation Measures for the Aleutian Cruise as required by NMFS

5. The GI gun was to be shut down if a North Pacific right whale was sighted from the vessel, even if it was located outside the safety radius, because of the rarity and sensitive status of this species.

6. To the extent practicable, the vessel was to avoid entering the critical habitat around Steller sea lion haul outs by operating in water depths >30 m. In fact, seismic surveys were not conducted in water <100 m deep. In addition, no-approach zones around Steller sea lion rookeries were observed except on two occasions when the vessel approached within 3 n.mi. (5.6 km) of • Bogoslof Island during the first day of transit from Dutch Harbor to the study area (20 Jul.), and • the rookery located on the southwest end of Kiska Island (2 Aug.). Seismic surveys were not being conducted during either of these incidents.
7. The vessel did not operate the GI gun within 3 n.mi. (5.6 km) of shore regardless of water depth unless it was during daylight hours and two MMOs were on duty to avoid potential disturbance to sea otters.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A). The primary purposes of MMOs aboard the *Thompson* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans and sea turtles to GI gun sounds with received levels >180 dB re μPa (rms), or of pinnipeds to >190 dB. ***(2)*** Document numbers of marine mammals and sea turtles present and any reactions to seismic activities. The data collected were used to estimate the number of marine mammals potentially affected by the project. Results of the monitoring effort are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were very similar to those during previous L-DEO seismic cruises. In chronological order, those were described by Smultea and Holst (2003), Smultea et al. (2003), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005), Smultea et al. (2005), and Holst et al. (2005a,b). The standard visual observation methods are described in Appendix D.

In summary, during the Aleutian survey, at least one MMO maintained a visual watch for marine mammals and sea turtles during all daylight hours while the vessel was in motion. During this cruise, two visual observers were on duty for 39% of the time when visual watches were underway. Visual observations were conducted from the *Thompson's* observation deck on the 03 level just below the bridge, or (during inclement weather) from the bridge itself. Observers focused their search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7×50 reticle binoculars, and mounted 25×150 Big-eye binoculars. Appendix D provides further details regarding visual monitoring methods.

Analyses

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories used were similar to those used during other recent L-DEO seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b). These categories are defined briefly below, with a more detailed description provided in Appendix D.

In general, data were categorized as "seismic" or "non-seismic". "Seismic" included all data collected while the GI gun was operating. Non-seismic included all data obtained before the GI gun was turned on (pre-seismic) or >2 h after the GI gun was turned off. Data collected during post-seismic

periods from 1.5 min to 2 h after cessation of seismic were considered either "recently exposed" (90 s–30 min) or "potentially exposed" (30 min–2 h) to seismic, and were excluded from analyses. Thus, the post-seismic data (90 s to 2 h after cessation of seismic) were not included in either the "seismic" or "non-seismic" categories. The 2-h post-seismic cut-off is the same cut-off used during the SE Alaska, Eastern Tropical Pacific off Central America, and Norway seismic cruises when relatively small seismic sources were also used (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a).

This categorization system was designed primarily to distinguish situations with ongoing seismic surveys from those where any seismic surveys were sufficiently far in the past that it can be assumed that they had no effect on current behavior and distribution of animals. The rate of recovery toward "normal" during the post-seismic period is uncertain. Therefore, the post-seismic period was defined so as to be sufficiently long (2 h) to ensure that any carry-over effects of exposure to the sounds from the single GI gun surely would have waned to zero or near-zero. The reasoning behind these categories is explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix D.

Line Transect Estimation of Densities

Marine mammal sightings during the "seismic" and "non-seismic" periods were used to calculate sighting rates (#/km). Sighting rates were then used to calculate the corresponding densities (#/km^2) of marine mammals near the survey ship during seismic and non-seismic periods. Density calculations were based on line-transect principles (Buckland et al. 2001). Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], only "useable" effort and sightings were included in density calculations. Effort and sightings were defined as "useable" when made under the following conditions: daylight periods both within the seismic survey area and during transit to and from that area, ***excluding*** periods 90 s to 2 h after the GI gun was turned off (post-seismic), or when ship speed <3.7 km/h (2 kt), or with seriously impaired sightability. The latter included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Bf >5 (Bf >2 for porpoises), or >60º of severe glare between 90º left and 90º right of the bow.

Correction factors for missed animals, i.e., $f(0)$ and $g(0)$, were taken from other related studies, as summarized by Koski et al. (1998) and Barlow (1999). This was necessary because of the low number of sightings of any individual species, and the inability to assess trackline sighting probability during a study of this type.

Densities during non-seismic periods were used to estimate the numbers of animals that presumably would have been present in the absence of seismic activities. Densities during seismic periods were used to estimate the numbers of animals present near the seismic operation and exposed to various sound levels. The difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability to visual observers. However, because of the limited duration of seismic operations during this study, the reported densities during seismic periods are not reliable indicators of actual densities present at those times. Thus, a comparison of densities observed during seismic and non-seismic periods is not a valid method for estimating changes in distribution or behavior during this study. Further details on the line transect methodology used during the survey are provided in Appendix D.

Analyses of marine mammal behavior in "seismic" vs. "non-seismic" conditions were only possible for odontocetes given the limited number of "useable" sightings and small amount of observation effort during seismic conditions.

Estimating Numbers Potentially Affected

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to GI gun pulses with received sound levels ≥160 dB re 1 μPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, the nominal 160 dB radii for the depth of water in which the survey took place was used (Table 3.1). The 160 dB radii used in these analyses were based upon a GI gun with a generator volume of 105 in^3—larger than the 45 in^3 generator volume of the GI gun actually used. Therefore, the numbers of marine mammals that may have been disturbed are probably overestimated by ~33%.

Two approaches were applied to estimate the numbers of marine mammals that may have been exposed to sound levels ≥160 dB re 1 μPa (rms):

1. Estimates of the numbers of potential *exposures* of marine mammals, and
2. Estimates of the number of different *individual* mammals exposed (one or more times).

The first method ("exposures") was obtained by multiplying the following three values: **(*A*)** km of seismic survey; **(*B*)** width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius); and **(*C*)** "corrected" densities of marine mammals estimated by line transect methods.

The second approach ("individuals") involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the study. In this method, areas ensonified to ≥160 dB on more than one occasion, e.g., when seismic lines crossed, were counted only once.

The two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals that would have been exposed to sound levels ≥160 dB re 1 μPa (rms) if they did not show avoidance reactions. The actual number is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys (Harris et al. 2001), and has recently been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b). The methodology is described in detail in these past reports and in Appendix D.

4. MARINE MAMMALS

Introduction

This chapter provides background information on the occurrence of marine mammals in the project area, and describes the results of the marine mammal monitoring program. In addition, numbers of marine mammals potentially affected during project operations are estimated.

Seismic operations were conducted along 537 km of trackline over a total of 44 h (Fig. 2.1; Table ES.1). In total, 4854 km of visual observations were conducted within the study area, including applicable effort during transit. "Useable" survey conditions, including daylight effort within and during transit to and from the study area, occurred during 35% (in hr) of the total visual effort (Table ES.1, Fig. 4.1). "Useable" effort excluded periods 90 s to 2 h after the GI gun was turned off, poor visibility conditions (visibility <3.5 km or extensive glare), Bf >5 (Bf >2 for porpoises), and ship speed <3.7 km/h (2 kt). The project provided data on the summer occurrence, distribution, and abundance of cetaceans in intermediate (100–1000 m) and deep (>1000 m) waters of the Aleutian Islands, an area where few systematic survey data had previously been collected.

The marine mammals that occur in the study area belong to four taxonomic groups: odontocetes (toothed cetaceans, including dolphins, porpoises and sperm whales), mysticetes (baleen whales), pinnipeds (seals and sea lions), and fissipeds (sea otter). Altogether, eighteen cetacean species and four species of pinnipeds are known to occur in the Aleutian Islands, along with the sea otter. Numbers of Steller sea lions, harbor seals, northern fur seals, and sea otters have been decreasing in the North Pacific region in the last several decades (Springer et al. 2003). Causes of the declines are poorly understood. However, it is evident that incidental mortality attributable to commercial fisheries and intentional harvesting of some species during the 1960s and 1970s played a role in the initial declines, and predation by killer whales is a contributing factor (Springer et al. 2003).

Monitoring Effort and Encounter Results

This section summarizes the visual monitoring effort and resulting sightings/detections from the *Thompson* during the Aleutian study from 20 July–20 August 2005. The study area is shown in Figure 2.1 and is defined in Chapter 3. The data categories and definitions used for analyses were discussed in Chapter 3. Summaries of results of visual monitoring are presented here, with detailed data summaries presented in Appendices F and G, including survey effort in both kilometers and hours. A general summary of effort and sightings is shown in Table ES.1.

Visual Survey Effort from the Thompson

All *Thompson* survey tracks are plotted by seismic activity (GI gun on or off) in Figure 2.1 and by visual survey effort (useable, non-useable, none) in Figure 4.1. During 9197 km of *Thompson* operations during the cruise, 2140 km of useable visual observations were made (Table ES.1). Useable survey effort, subdivided by GI gun on or off and water depth strata, is shown in Appendix F.1. MMOs observed during all daylight seismic periods. MMOs observed primarily (63% of watch time) from the bridge, with the remaining observations conducted from the 03 deck.

Beaufort Wind Force during observations ranged from 1 to 7, with 86% of the observation effort in conditions of Bf ≤5 (i.e., useable for most species). About 71% of the useable observation effort (Bf 1 to 5) occurred during Bf ≤3 (wind speed 0.0–5.1 m/s; Appendix F.2) and 9% occurred during Bf <2.

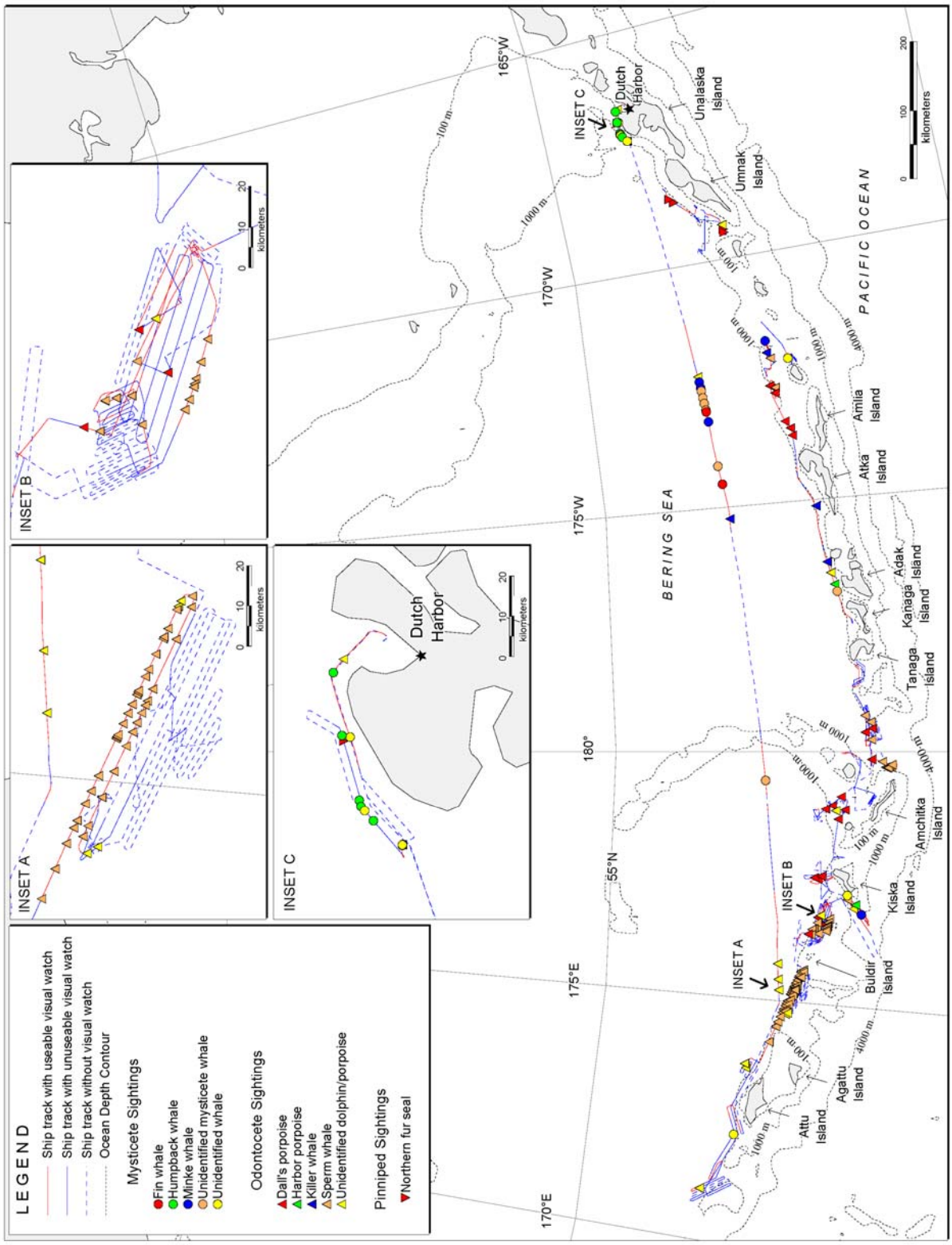

FIGURE 4.1. *Thompson* survey tracks with and without visual effort, and marine mammal sightings, during the rock dredging and seismic study off the Aleutian Islands, 20 July – 20 August 2005.

Visual Sightings of Marine Mammals and Other Vessels

Numbers of Marine Mammals Seen.—An estimated 381 individual cetaceans were seen in ~144 groups during the study period (Table. 4.1). Seven different cetacean species were identified (Table 4.1) with Dall's porpoise being the most abundant (n = 99 individuals in 19 groups), followed by sperm whales (n = 78 in 72 groups; Table 4.1). Many of the unidentified dolphin/porpoise sightings exhibited similar behavior to groups of Dall's porpoises, but rapid movements or great distances from the vessel often precluded positive identification. In addition, five groups (nine individuals) of northern fur seals were sighted. A detailed list of sightings is provided in Appendix F.3.

Most of the 149 sightings (68% or 101 groups) made within the study area, including transits, were "useable" (Tables 4.1, 4.2). These "useable" sightings, along with the corresponding effort data, are the basis for the ensuing analyses comparing sighting rates, behaviors, and densities of marine mammals during seismic and non-seismic periods.

Sightings with GI Gun On.—Of the total 149 sightings, 35 were made while the GI gun was on, 112 were made during non-seismic periods, and the remaining 2 were noted during "post-seismic" periods (i.e., Tables ES.1 and 4.1; Appendix F.4).

The GI gun was shut down once when a group of seven Dall's porpoises approached near the designated safety radius. Further detail on this encounter is provided later in this chapter (see *Cetaceans Potentially Exposed to Sounds ≥180 dB*) and in Appendix G.

Sighting Rates.—Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 4.3. Based on the number of groups seen per kilometer, the sighting rate was nearly nine times as high during seismic as during non-seismic conditions (Table 4.3). These results are potentially unrepresentative given the disproportionate amounts of visual effort (Table ES.1) and a heterogeneous distribution of sperm whales within the study area (Fig. 4.1). Estimated densities (#/km^2) were also much higher during seismic vs. non-seismic periods as discussed later in this chapter (also see Appendix G); again, densities during seismic are based on limited effort and are probably not representative of densities in the general study area.

The most common reason sightings were considered unuseable was due to poor visibility (<3.5 km) caused by fog. During non-seismic periods, detection rate in unusable periods was about half that in useable periods, consistent with what would be expected during periods of poor vs. good visibility (Table 4.3). For seismic periods, the difference in detection rate between useable and unuseable periods was even greater (Table 4.3). This was largely attributable to inflation of the useable detection rate caused by the high concentration of sperm whales encountered during seismic transects near Buldir Island (Fig. 4.1 inset A), as discussed in the following section. The difference noted for non-seismic periods is more realistic of the actual difference in detection rates during useable and unuseable conditions.

Other Vessels—The IHA required that MMOs record the number and characteristics of vessels <5 km from any marine mammal sightings (Appendix A). There were few vessels near the *Thompson* during the study. Those that were present in the eastern half of the study area were generally large cargo vessels or container ships. A number of small fishing boats were also seen in the eastern half of the study area, especially near Dutch Harbor. Most of these vessels were at distances >5 km from any cetaceans sighted by MMOs and no obvious reactions by marine mammals to other vessel were observed.

TABLE 4.1. Numbers of sightings and of individual marine mammals, both ***(A)*** total and ***(B)*** useable[a], observed from the *Thompson* in the study area (including transits) during the Aleutian cruise, 20 July–20 August 2005.

	Seismic		Post-Seismic		Non-Seismic		Total	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
A. All Sightings								
Mysticetes								
Fin whale	0	0	0	0	2	4	2	4
Humpback whale	0	0	0	0	8	16	8	16
Minke whale	0	0	0	0	5	8	5	8
Unidentified mysticete whale	0	0	0	0	7	11	7	11
Unidentified whale	0	0	0	0	6	6	6	6
Odontocetes								
Dall's porpoise	1	7	1	5	17	87	19	99
Harbor porpoise	0	0	0	0	3	15	3	15
Killer whale	0	0	0	0	5	21	5	21
Sperm whale	31	33	0	0	41	45	72	78
Unidentified dolphin/porpoise	3	23	1	5	13	95	17	123
Total Cetaceans	35	63	2	10	107	308	144	381
Pinnipeds								
Northern fur seal	0	0	0	0	5	9	5	9
B. Useable[a] Sightings								
Mysticetes								
Fin whale	0	0	N/A	N/A	2	4	2	4
Humpback whale	0	0	N/A	N/A	2	5	2	5
Minke whale	0	0	N/A	N/A	4	6	4	6
Unidentified mysticete whale	0	0	N/A	N/A	7	11	7	11
Unidentified whale	0	0	N/A	N/A	2	2	2	2
Odontocetes								
Dall's porpoise	0	0	N/A	N/A	1	5	1	5
Harbor porpoise	0	0	N/A	N/A	3	15	3	15
Killer whale	0	0	N/A	N/A	5	21	5	21
Sperm whale	30	32	N/A	N/A	31	34	61	66
Unidentified dolphin/porpoise	2	20	N/A	N/A	10	66	12	86
Total Cetaceans	32	52	N/A	N/A	67	169	99	221
Pinnipeds								
Northern fur seal	0	0	N/A	N/A	2	3	2	3

Note: N/A means not applicable; useable sightings excluded sightings during post-seismic periods.
[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *List of Acronyms and Abbreviations*.

Additional Sightings during Transit back to Dutch Harbor

During the transit back to Dutch Harbor after the final rock dredge, all of the observation equipment had already been put away. Thus, sightings made during the last 3 h of observer effort were considered incidental and not included in the data analyses. During those 3 h, a group of five Dall's porpoises was sighted, plus one group of eight killer whales, and an estimated 30–40 humpback whales, some in groups of up to four individuals. None of these animals appeared to be actively feeding. These sightings occurred off Cape Cheerful, northeastern Unalaska Island, in Bf 2–5, and visibility >3.5 km.

TABLE 4.2. Number of marine mammal sightings from the *Thompson* during the Aleutian cruise, 20 July–20 August 2005, and number that were "useable" in analyses.[a] Numbers in parentheses are numbers of individuals.

	Sightings Groups (# Indiv.)	
Species	All	Useable[a]
Fin whale	2 (4)	2 (4)
Humpback whale	8 (16)	2 (5)
Minke whale	5 (8)	4 (6)
Dall's porpoise	19 (99)	1 (5)
Harbor porpoise	3 (15)	3 (15)
Killer whale	5 (21)	5 (21)
Sperm whale	72 (78)	61 (66)
Unidentified mysticete whale	7 (11)	7 (11)
Unidentified whale	6 (6)	2 (2)
Unidentified dolphin/porpoise	17 (123)	12 (86)
Northern fur seal	5 (9)	2 (3)
Total	**149 (390)**	**101 (225)**

[a] Useable detections are those made during useable daylight visual observations; see *Acronyms and Abbreviations* for the definition of "useable" observation effort.

TABLE 4.3. Encounter rates for sightings from the *Thompson* during the Aleutian cruise, 20 July–20 August 2005.

	Non-Seismic			Seismic			Total		
Effort Type	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)
Useable[a]	69	2030	34.0	32	110	290.9	101	2140	47.2
Non-Useable[b]	45	2544	17.7	3	169	17.8	48	2713	17.7
All	114	4575	24.9	35	279	125.4	149	4854	30.7

[a] Useable detections are those made during useable daylight visual observations as defined in *Acronyms and Abbreviations*.
[b] Includes the *"Post-seismic"* category

Distribution of Cetaceans

Cetacean sightings in the study area are plotted in Figure 4.1. As noted earlier, to our knowledge, no systematic vessel-based surveys had been conducted in the western Aleutians prior to this survey.

Observations during the Aleutian study suggest that the Dall's porpoise and sperm whale are the primary cetacean species in the study area. The large number of Dall's porpoise sightings was expected based on limited previous survey efforts. Dall's porpoises were seen throughout our survey area wherever visual observations occurred, including before, during, and after the seismic operations (Fig. 4.1; Appendix F.3).

A large number of the sperm whale sightings (n = 61) occurred in the waters surrounding Buldir Island. The large number of sperm whales was not expected based upon data from previous survey efforts. The locally high concentration of sperm whales found in waters surrounding Buldir Island suggests that the area may be a summer feeding ground. Such concentrations are not atypical for the species. Because these whales

were encountered within one of the short seismic periods during this cruise, it significantly affected the sighting rates. It is possible that some sightings were repeat sightings of the same individuals, given the close spacing of seismic lines in that region (Fig. 2.1, 4.1), although none were confirmed to be resightings. It is also possible that many more sperm whales were present in the area than were sighted, because sperm whales sometimes dive for long periods (up to ~1 h) when they are feeding.

Humpback whales were seen near Cape Cheerful (Unalaska Isl.) during transits to and from the main study area. This location is likely a feeding area, although no active feeding by humpbacks was recognized.

Marine Mammal Behavior

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data include estimated closest observed points of approach to the vessel when the GI gun was and not firing (CPA), movement relative to the vessel or GI gun when the gun was and was not firing, and observed behavior of animals that were sighted. Only sperm whales and Dall's porpoises (including unidentified dolphin/porpoise sightings, which were believed to be primarily Dall's porpoises but could not be positively identified) were seen during both seismic and non-seismic periods. Thus, in this section, comparisons between seismic and non-seismic periods are possible only for these two species.

Closest Observed Point of Approach

Considering only useable sightings, Dall's porpoises were seen closer to the GI gun when it was off than when it was on, (mean CPA 651 vs. 1588 m; n = 11 vs. 2 groups; Table 4.4). Sperm whales tended to be seen at about the same distances regardless whether the GI gun was off or on (mean CPA 2503 vs. 2897 m, n = 31 vs. 30 groups; Table 4.4). The mean CPA distance noted during seismic periods (Table 4.4) may be underestimated if some animals avoided the GI gun at distances beyond those where they could be detected by MMOs. However, sighting rates were actually higher during seismic than non-seismic periods (Table 4.3). In fact, on one occasion, a group of 7 Dall's porpoises approached the operating GI gun within 30 m; however, this sighting was unuseable due to rough seas (Bf = 6), so it is not listed in Table 4.4. The received level for this group (when below the surface) was >160 dB. Mean CPA for mysticetes was similar to that of odontocetes during non-seismic periods. Pinnipeds tended to be seen closer to the vessel than were cetaceans (Table 4.4).

Sample sizes are small, but results from this and other cruises are consistent with the expectation that seismic sounds displace some cetaceans (Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b). Displacement may be related to the size of the sound source, but that cannot be assessed based on this study alone.

Categories of Behavior

Cetacean behavior is difficult to observe. Cetaceans are often at the surface only briefly, and there are difficulties in resighting individuals or groups, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Limited behavioral data were collected during this project because cetaceans were often seen at a distance from the vessel, and they were typically not tracked for long distances or durations while the vessel was underway. The two parameters that were examined quantitatively to assess potential seismic effects on cetacean behavior were the behavior and movement when the animal(s) were first observed (see Appendix D for variables and definitions). The CPA distance recorded for each sighting was also an indicator of behavior (see above and Appendix D).

TABLE 4.4. Closest observed points of approach (CPA) of useable marine mammal sightings to the GI gun during non-seismic and seismic periods during the Aleutian cruise, 20 July–20 August 2005. For all useable sightings during seismic, the estimated received level at CPA was ≤160 dB re 1 µPa, rms.

		Non-seismic				Seismic			
Group[a]	No. of Groups	Mean CPA (m)	s.d.	*n*	Range (m)	Mean CPA (m)	s.d.	*n*	Range (m)
Mysticetes	17	1669	1408	17	77 - 5376	N/A	N/A	0	N/A
Odontocetes									
Harbor Porpoise	3	630	51	3	571 - 660	N/A	N/A	0	N/A
Delphinid	5	752	409	5	122 - 1127	N/A	N/A	0	N/A
Dall's porpoise[b]	13	651	350	11	166 - 1296	1588	1616	2	445 - 2730
Sperm whale	61	2503	1308	31	216 - 5347	2897	1599	30	292 - 5376
Total Odontocetes	82	1808	1375	50	122 - 5347	2815	1606	32	292 - 5376
Pinnipeds	2	180	99	2	110 -250	N/A	N/A	0	N/A

Note: N/A means data not available.
[a] Includes only useable sightings as defined in *Acronyms and Abbreviations.*
[b] Dall's porpoise category also includes unidentified dolphin/porpoise sightings, which were believed to be primarily Dall's porpoises but could not be positively identified.

Sample sizes within this one cruise, especially during seismic periods, were small. However, when combined with results from other cruises, the data may be useful in assessing behavioral reactions of cetaceans to seismic sounds. Results are presented in Tables 4.5 and 4.6.

Movement.—During both seismic and non-seismic periods, sperm whales were most often (63 and 84% of sightings with known movements, respectively) seen logging at the surface or exhibiting no movement relative to the vessel (Table 4.5). The most frequently-observed behavior for Dall's porpoises was swimming parallel to the vessel (9 of 13 sightings). Mysticetes were only observed during periods without seismic, most frequently swimming parallel to the vessel (9 of 17 sightings; Table 4.5).

First Observed Behavior.—The most common first behavior recorded for sperm whales during both seismic and non-seismic periods was logging/resting (Table 4.6). Logging was the first observed behavior for 45% of sperm whale sightings during non-seismic periods, and 57% during seismic operations (Table 4.6). Dall's porpoises were first seen porpoising during 82% of non-seismic sightings and 100% (n=2) of sightings during seismic operations. Mysticetes were only seen during non-seismic periods; the most commonly observed behavior was swimming. Pinnipeds were seen either swimming or resting at the surface (Table 4.6).

Mitigation Measures Implemented

The GI gun was shut down on one occasion because a group of seven Dall's porpoises was seen approaching the safety radius as described below. The shut down occurred quickly when called for by the MMO. The group was not seen subsequently within the safety radius so it is unlikely that the porpoises were exposed to sounds ≥180 dB re 1 µPa (rms).

- A single group of seven Dall's porpoises was initially observed 180 m to the stern and swimming towards the vessel during daylight seismic operations on 5 Aug. at 00:57 GMT (4 Aug. 16:57 ADT). Over the next 2 min, the group repeatedly approached and departed the GI gun and stern of the vessel in a zig-zag manner but remained outside the nominal (Table 3.1) 27-m safety radius. At

TABLE 4.5. Movements of useable marine mammal sightings during non-seismic and seismic periods during the Aleutian cruise, 20 July–20 August 2005. See Appendix D for definitions of movement categories.

	Movement Relative to Vessel							
Group[a]	**Mill**	**Swim Perpen-dicular**	**Swim Away**	**Swim Parallel**	**Swim Toward**	**No movement**	**Unknown**	**Total**
Mysticetes								
Non-seismic	0	4	0	9	0	0	4	**17**
Seismic	0	0	0	0	0	0	0	**0**
Total	**0**	**4**	**0**	**9**	**0**	**0**	**4**	**17**
Odontocetes								
Harbor Porpoise								
Non-seismic	0	1	2	0	0	0	0	**3**
Seismic	0	0	0	0	0	0	0	**0**
Total	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**3**
Delphinid								
Non-seismic	1	1	0	2	1	0	0	**5**
Seismic	0	0	0	0	0	0	0	**0**
Total	**1**	**1**	**0**	**2**	**1**	**0**	**0**	**5**
Dall's porpoise[b]								
Non-seismic	0	0	0	9	1	0	1	**11**
Seismic	0	0	1	0	1	0	0	**2**
Total	**0**	**0**	**1**	**9**	**2**	**0**	**1**	**13**
Sperm whale								
Non-seismic	3	0	1	3	0	18	6	**31**
Seismic	1	3	3	3	0	14	6	**30**
Total	**4**	**3**	**4**	**6**	**0**	**32**	**12**	**61**
Total Odontocetes								
Non-seismic	4	2	3	14	2	18	7	**50**
Seismic	1	3	4	3	1	14	6	**32**
Total	**5**	**5**	**7**	**17**	**3**	**32**	**13**	**82**
Pinnipeds								
Non-seismic	1	0	0	0	0	1	0	**2**
Seismic	0	0	0	0	0	0	0	**0**
Total	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**2**

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations*.
[b] Dall's porpoise category also includes unidentified dolphin/porpoise sightings, which were believed to be Dall's porpoises but could not be positively identified.

00:59 (GMT) the group appeared to be about to enter the safety radius and the MMO called for a shut down of the GI gun. The shutdown was executed quickly and likely occurred before the porpoises entered the nominal safety radius, if they entered it at all, as the porpoises were not again seen by the MMO.

Another mitigation measure that was implemented (on two occasions) involved starting the GI gun outside the 20 n.mi critical habitat buffer for Steller sea lions, and then re-entering the buffer area to conduct a seismic transect. This was necessitated when poor sighting conditions within the critical habitat buffer did not allow the entire applicable safety radius to be monitored by MMOs, and thus did not allow startup within the buffer area.

TABLE 4.6. Comparison of first observed behavior of useable marine mammal groups during non-seismic and seismic periods during the Aleutian cruise, 20 July–20 August 2005[a]. See Appendix D for definitions of behavior.

Group[a]	Porpoise	Swim	Dive	Breach	Blow	Fluke	Log/Rest	Mill	Unknown	Total
Mysticetes										
Non-seismic	0	12	0	1	3	0	0	0	1	**17**
Seismic	0	0	0	0	0	0	0	0	0	**0**
Total	**0**	**12**	**0**	**1**	**3**	**0**	**0**	**0**	**1**	**17**
Odontocetes										
Harbor Porpoise										
Non-seismic	2	0	0	0	0	0	1	0	0	**3**
Seismic	0	0	0	0	0	0	0	0	0	**0**
Total	**2**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**3**
Delphinid										
Non-seismic	0	5	0	0	0	0	0	0	0	**5**
Seismic	0	0	0	0	0	0	0	0	0	**0**
Total	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**
Dall's porpoise[b]										
Non-seismic	9	2	0	0	0	0	0	0	0	**11**
Seismic	2	0	0	0	0	0	0	0	0	**2**
Total	**11**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13**
Sperm whale										
Non-seismic	0	5	1	0	9	1	14	1	0	**31**
Seismic	0	3	0	0	9	1	17	0	0	**30**
Total	**0**	**8**	**1**	**0**	**18**	**2**	**31**	**1**	**0**	**61**
Total Odontocetes										
Non-seismic	11	12	1	0	9	1	15	1	0	**50**
Seismic	2	3	0	0	9	1	17	0	0	**32**
Total	**13**	**15**	**1**	**0**	**18**	**2**	**32**	**1**	**0**	**82**
Pinnipeds										
Non-seismic	0	1	0	0	0	0	1	0	0	**2**
Seismic	0	0	0	0	0	0	0	0	0	**0**
Total	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**2**

[a] Includes only useable detections as defined in Acronyms and Abbreviations.

[b] Dall's porpoise category also includes unidentified dolphin/porpoise sightings, which were believed to be primarily Dall's porpoises but could not be positively identified.

Estimated Number of Marine Mammals Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 µPa (rms) is variable. It depends on water depth, source depth, water-mass and bottom conditions, and—for directional sources—aspect (Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at or near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b).

Disturbance and Safety Criteria

Any marine mammal that might have been exposed to GI gun pulses with received sound levels ≥160 dB re 1 µPa (rms) was, in one set of calculations that follow, assumed to have been potentially disturbed. Such disturbance was authorized by the IHA issued to L-DEO. However, the 160-dB criterion was developed by NMFS from studies of baleen whale reactions to seismic pulses (Richardson et al. 1995). That criterion likely is not appropriate for delphinids, Dall's porpoise, or pinnipeds. The hearing of small odontocetes is relatively insensitive to low frequencies. Also, behavioral reactions of small odontocetes and pinnipeds to airgun sounds indicate that many of them are less responsive than are some baleen whales (Richardson et al. 1995; LGL Ltd. 2003a,b; Gordon et al. 2004; MacLean and Koski 2005). Probable exposure to received levels ≥170 dB was used as an alternative criterion in estimating potential disturbance of delphinids, Dall's porpoise, and pinnipeds.

Table 3.1 shows the distances at which various sound levels are estimated to be received in two different water depth categories from a single GI gun. The predicted 160 and 170-dB radii (assumed disturbance criteria for marine mammals) are based on modeling and limited acoustic measurements in the northern Gulf of Mexico (Tolstoy et al. 2004a,b). During the present project, NMFS required that mitigation measures be applied to avoid or minimize the exposure of cetaceans (and sea turtles), and of pinnipeds, to impulse sounds with received levels ≥180 dB and ≥190 dB re 1 µPa (rms), respectively. The safety radii, along with the other distances, were used to estimate numbers of marine mammals exposed to various received sound levels. These safety radii and estimated numbers of disturbances were based upon a single GI gun sound source with a generator volume of 105 in^3. The GI gun actually used during the Aleutian study had a generator volume of 45 in^3. Therefore, the radii and estimated numbers of "takes" are ~33% greater than necessary for the lower volume GI gun used during the study.

This section applies several methods to estimate the number of marine mammals exposed to seismic sound levels strong enough that they might have caused disturbance or other effects. The procedures include ***(A)*** minimum estimates based on direct observations, ***(B)*** estimates based on marine mammal densities obtained in the study area via visual observations from the *Thompson* during periods unaffected by seismic surveys, and ***(C)*** estimates based on densities obtained by observers aboard the *Thompson* while seismic surveys were being conducted in the study area. The actual number of individual marine mammals exposed to, and potentially affected by, strong seismic survey sounds likely was between the minimum and maximum estimates provided below. The estimates provided here are based on observations during this project. In contrast, the estimates provided in the IHA Application and EA for this project (LGL Ltd. 2004a,b) were based on survey and other information available prior to this project, and assumed that there would be more seismic surveying than actually occurred.

Estimates from Direct Observations

The number of marine mammals observed close to the *Thompson* during the Aleutian study provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers.

Marine Mammals Potentially Exposed to Sounds ≥180 dB re 1 µPa (rms).—During this project, no marine mammals were sighted within the small 180-dB radius around the GI gun and it is therefore unlikely that any marine mammals received sound levels in excess of 180 dB. One shut down was undertaken in order to avoid exposing a group of 7 Dall's porpoises to sound levels ≥180 dB. Because

this group of porpoises was not seen within the nominal safety radius, before or after the shutdown, and because they approached the seismic vessel while they were at the surface, it is unlikely that they were exposed to sound levels in excess of 180 dB.

The estimated 180-dB radii shown in Table 3.1 are the *maximum* distances from the GI gun where sound levels were expected to be ≥180 dB re 1 μPa (rms). These distances would apply at the water depth with maximum received level. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

- Near the water surface, received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove.
- Some cetaceans may have been within the predicted 180 dB radii and/or within the safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO station on the bridge was ~87 m forward of the GI gun, and the tip of the *Thompson's* bow was ~108 m away from the GI gun. The safety zone was not centered on the observer's station, but rather on the GI gun. This offset in location between GI gun and observer was accounted for in the observer's decisions regarding whether it was necessary to shut down the GI gun for sightings immediately forward or astern.

Marine Mammals Potentially Exposed to Sounds ≥160 dB re 1 μPa (rms).—Thirty-five groups of cetaceans were sighted during the Aleutian cruise when the GI gun was operating (Appendices F.3 and F.4). These 35 groups included 31 sperm whale groups, 1 Dall's porpoise group, and 3 unidentified dolphin/porpoise groups. All 35 groups were believed to be unique groups. Only the one group of 7 Dall's porpoises that caused the shut down is believed to have entered the ≥160 dB radius (see Appendix F.3 for sightings). All these groups were sighted in intermediate (100-1000 m) or deep (>1000 m) water.

Estimates Extrapolated from Marine Mammal Density

The number of marine mammals sighted during the Aleutian study presumably underestimates the actual number present during the survey because some animals present near the trackline would not be seen by the observers. During daylight, this occurs if the animals were below the surface when the ship was nearby. Some other mammals, even if they surfaced near the vessel, would be missed because of limited visibility, high Bf, glare, or other factors limiting sightability. The ability to detect cetaceans within and beyond ~2–3 km was no doubt reduced, especially for smaller animals and small groups, during less than ideal viewing conditions, which were very common. Suboptimal viewing conditions presumably caused a stronger reduction in the ability to detect pinnipeds as compared with cetaceans.

Furthermore, some animals would be expected to avoid the area near the seismic vessel while the GI gun was firing (see Richardson et al. 1995; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Within the assumed 160–170 dB radii around the source (i.e., ~90–410 m in waters >100 m deep), the distribution and behavior of cetaceans likely was altered as a result of the seismic survey as a result of reactions to the GI gun or to the vessel itself. The extent to which the distribution and behavior of pinnipeds would be reduced within that area is less certain, given variable previous results (Thompson et al. 1998; Harris et al. 2001).

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, ≥180 dB and ≥190 dB, and to estimate corrected marine mammal densities, was described briefly in Chapter 3 *Analyses* and in further depth in Appendix D. Densities based on the number of sightings made during

the cruise were calculated for both non-seismic and seismic periods. The former represent the densities of mammals expected to occur "naturally" within the area. The latter represent the densities of mammals that apparently remained within the area exposed to strong sound pulses. Given the small 160 dB radius around the single GI gun, animals displaced from that zone might still be visible. Thus, for a small-source project like this one, one would not expect large differences in the apparent densities with vs. without seismic operations.

The aforementioned corrected densities were used to estimate both the number of *individual* marine mammals exposed to 160, 170, 180, and 190 dB, and the number of *exposures* of different individual marine mammals. These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix D.

Table 4.8 is a summary of the estimated numbers of marine mammals exposed to received sounds with levels ≥160 dB and ≥170 dB relative to the number of "takes" requested in the IHA Application. A similar summary of estimated marine mammal exposures to sounds ≥180 dB and ≥190 dB is provided in Table 4.9. The data used to calculate these numbers, for non-seismic as well as seismic periods, are presented in Appendices G.1–G.5 for the criteria of interest. Note that the estimated numbers in Tables 4.8 and 4.9 represent the animals that would have been exposed had the animals not shown localized avoidance of the GI gun or the ship itself. Given the small 180- and 190-dB radii, it is probable that many of the animals calculated (based on density) to be within the 180- or 190-dB zones would in fact move away before being exposed to sounds that strong. Also note that the radii used for all estimates were appropriate for a 105 in^3 GI gun, but the GI gun actually used during the study had generator volume 45 in^3. Therefore, estimates are ~33% overstated.

Estimated Numbers of Cetaceans Exposed to ≥160 or ≥170 dB.—It is assumed that non-delphinid cetaceans are likely to be disturbed appreciably if exposed to received levels of seismic pulses ≥160 dB re 1 μPa (rms). It is assumed that delphinids and Dall's porpoises are unlikely to be disturbed appreciably unless exposed to received levels ≥170 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB.

Estimates Based on Densities during Non-seismic Periods: "Corrected" estimates of the densities of cetaceans present during non-seismic periods are given in Appendices G.1 and G.2. These corrected densities were used to estimate the number of cetaceans that were exposed to ≥160 and ≥170 dB, and thus potentially disturbed by seismic operations (Table 4.9).

(A) 160 dB (rms): We estimate that there would have been ~19 exposures of ~19 different individual cetaceans to ≥160 dB during the Aleutian survey if the cetaceans remained stationary throughout the study (Table 4.9).

(B) 170 dB (rms): On average, delphinids and Dall's porpoises may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures of these groups would be ~1/3rd of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB than ≥160 dB. Overall, based on densities estimated from surveys during non-seismic periods, the estimated number of delphinid and Dall's porpoise exposures to ≥170 dB was ~1, which is ~25% of the expected exposures to ≥160 dB (4). The number of individual delphinids and Dall's porpoises exposed to ≥170 dB (or that moved away before the received level reached 170 dB) is also estimated to have been 1.

TABLE 4.8. Estimated numbers of exposures, and estimated minimum numbers of individual marine mammals exposed, to sounds with received levels ≥160 dB re 1 µPa rms (and ≥170 dB for delphinids and Dall's porpoise), based on observed densities during non-seismic and seismic periods during the Aleutian cruise. Radii were appropriate for a 105 in^3 GI gun but a 45 in^3 GI gun was actually used. Therefore, values here are ~33% overestimated. Also shown is the "harassment take" authorized by NMFS under the IHA. Species in italics are listed under the ESA as endangered.

	Estimated numbers exposed to ≥160 dB re 1 µPa (rms) (and ≥170 dB) based on observations during **non-seismic periods** [1]		Estimated numbers exposed to ≥160 dB re 1 µPa (rms) (and ≥170 dB) and based on observations during **seismic periods** [1]		Requested take
	Exposures	Individuals	Exposures	Individuals	
Odontocetes					
Delphinidae					
Pacific white-sided dolphin	0 (0)	0 (0)	0 (0)	0 (0)	44
Risso's dolphin	0 (0)	0 (0)	0 (0)	0 (0)	5
Unidentified dolphin	0 (0)	0 (0)	0 (0)	0 (0)	
Killer whale	3 (1)	3 (1)	0 (0)	0 (0)	157
Short-finned pilot whale	0 (0)	0 (0)	0 (0)	0 (0)	10
Total Delphinidae					
Phocoenidae					
Dall's porpoise	1 (0)	1 (0)	0 (0)	0 (0)	898
Total Delphinidae & Dall's porpoise	**4 (1)**	**4 (1)**	**0 (0)**	**0 (0)**	1114
Harbor porpoise	2	2	0	0	381
Unidentified porpoise/dolphin	9	9	62	62	
Physeteridae					
Sperm whale	*2*	*2*	41	*41*	*8*
Ziphiidae					
Cuvier's beaked whale	0	0	0	0	12
Baird's beaked whale	0	0	0	0	14
Stejneger's beaked whale	0	0	0	0	5
Monodontidae					
Beluga	0	0	0	0	5
Mysticetes					
North Atlantic right whale	*0*	*0*	*0*	*0*	*3*
Gray whale	0	0	0	0	90
Humpback whale	*0*	*0*	*0*	*0*	*121*
Minke whale	0	0	0	0	37
Sei whale	0	0	0	0	*5*
Fin whale	0	0	0	0	*120*
Blue whale	0	0	0	0	*5*
Unidentified mysticete	1	1	0	0	
Unidentified whale	0	0	0	0	
Total Other Cetaceans	**15**	**15**	**103**	**103**	**806**
Total Cetaceans	**19**	**19**	**103**	**103**	**1920**
Pinnipeds					
Northern fur seal	0 (0)	0 ()	0 (0)	0 (0)	24
Steller sea lion	0 (0)	0 ()	0 (0)	0 (0)	95
Harbor seal	0 (0)	0 ()	0 (0)	0 (0)	48
Ribbon seal	0 (0)	0 ()	0 (0)	0 (0)	5
Total Pinnipeds	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**172**

[1] Survey effort, numbers of sightings and densities on which these estimates arre based are provided in Appendices G.1 and G.2 (non-seismic periods) and G.3 and G.4(seismic periods).

TABLE 4.9. Estimated numbers of exposures, and estimated minimum numbers of individual marine mammals exposed, to sounds with received levels ≥180 dB re 1 µPa rms (and ≥190 dB for delphinids and Dall's porpoise) during the Aleutian cruise. Radii were appropriate for a 105 in^3 GI gun but a 45 in^3 GI gun was actually used. Therefore, values here are ~33% overestimated. Based on calculated densities[a] in seismic periods (e.g., Tables G.3 and G.4).

Species/species group	Numbers of exposures[a]						Minimum number of individuals[a]					
Water depth (m)	100-1000		>1000		All depths		100-1000		>1000		All depths	
Area in km^2 ensonified to ≥180 dB (≥190 dB)	0	(0)	0	(0)			0	(0)	0	(0)		
Odontocetes												
Delphinidae												
Unidentified dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Killer whale	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Phocoenidae												
Dall's porpoise	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Delphinidae & Dall's porpoise	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**
Harbor porpoise	0		0		0		0		0		0	
Unidentified porpoise/dolphin	6		0		6		6		0		6	
Physeteridae												
Sperm whale	2		2		4		2		2		4	
Mysticetes												
Humpback whale	0		0		0		0		0		0	
Minke whale	0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0	
Unidentified mysticete	0		0		0		0		0		0	
Unidentified whale	0		0		0		0		0		0	
Total Other Cetaceans	**10**		**4**		**14**		**10**		**4**		**14**	
Total Cetaceans	**10**		**4**		**14**		**10**		**4**		**14**	
Pinnipeds												
Northern fur seal	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Pinnipeds	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**

[a] Slight apparent discrepancies in totals result from rounding to integers.

Estimates Based on Densities during Seismic Periods: The densities of cetaceans during seismic periods (539/1000 km^2 in 100-1000 m depths and 102/1000 km^2 in >1000 m depths; Appendix G.3 and G.4) were ~1.6 to 11 times those during non-seismic periods (48.9/1000 km^2 and 62.5/m/km^2; Appendix G.1 and G.2). Because of the small amount of survey effort during seismic periods, these densities are not reliable estimates of numbers that may have been present in other areas. However, the high number of sightings (32 useable sightings) indicates that marine mammals were locally abundant in the area where seismic work was conducted. This local abundance was likely due to attraction of cetaceans to locally abundant food resources in some areas where seismic happened to be conducted. In any event, based on the corrected densities recorded during seismic periods, the minimum numbers of exposures and minimum numbers of individuals exposed are summarized in Table 4.8. For additional details, see Appendix G.

Cetaceans Potentially Exposed to Sounds ≥180 dB.—It is possible that some cetaceans that were at the surface within the 180 dB radius (27 to 41 m, depending on water depth) for the GI gun during daylight observation periods were missed by the observers. Based on the densities of cetaceans estimated from observations during seismic periods, ~14 cetacean exposures and 14 individuals would have been expected to occur within the 180 dB radius around the operating GI gun (Table 4.9). The latter estimate is about twice the seven different individual cetaceans that direct observations indicated were possibly, yet not likely, exposed to ≥180 dB (Table 4.7). The difference could result from the fact that the esti-

mates in Table 4.9 include any animals that, in fact, avoided exposure to ≥180 dB by swimming away from the approaching seismic vessel.

Pinnipeds Potentially Exposed to Sounds ≥160, 170, 180 and 190 dB.—The northern fur seal was the only species of pinniped sighted during this cruise and densities of pinnipeds were estimated to be very low (0.0 to 2.5/1000 km^2, Appendix H). No pinnipeds are estimated to have been exposed to seismic sounds with received levels ≥160 dB re 1 µPa (rms) based on densities observed during non-seismic or seismic periods (Tables 4.8 and 4.9).

Summary of Exposure Estimates.— Estimates of the numbers of exposures to strong sounds are considered *maximum* estimates of the number of mammals exposed. In this method, repeated exposures of some of the same animals are counted separately, with no allowance for overlapping survey lines. This method, when based on densities during non-seismic periods, also assumes that no mammals show avoidance of the approaching seismic vessel before received sound levels reach the sound level in question. Based on corrected densities of cetaceans observed during non-seismic periods, a maximum of ~19 potential cetacean exposures to GI gun sounds with received levels ≥160 dB re 1 µPa might have occurred during the seismic survey. The estimates are lower if based on the alternative ≥170 dB criterion for delphinids and Dall's porpoise (Table 4.8); 1 individual delphinid or Dall's porpoise is estimated to have been exposed to ≥170 dB compared to 4 individuals based on the >160 dB criterion. During this survey, based on a very small amount of observation effort, densities of marine mammals near the survey vessel were much higher during seismic than non-seismic periods. Based on corrected densities of marine mammals observed during seismic periods, 103 marine mammals may have been exposed to sounds ≥160 dB. These included 41 sperm whales and 62 unidentified dolphins/porpoises.

The highest overall estimate of exposures to ≥160 dB (n = 103) is only about 5% of the potential "take" estimated in the IHA Application. There are two reasons for the difference. First, the requested take authorization was based on ***maximum*** numbers of marine mammals that might occur in the survey area during the survey period, an approach that tends to overestimate the number ***likely*** to be there. Second, much less seismic surveying was done than was assumed in the IHA Application because the MBB sonar produced maps detailed enough for the geologists to identify dredge targets without the aid of seismic data. Note that the 103 estimate *does* include approximate allowance for animals missed by the observers during daytime. That allowance is based on application of "best available" correction factors for missed animals [i.e., $f(0)$ and $g(0)$ factors] during daytime.

Summary and Conclusions

L-DEO's marine mammal monitoring program provided concentrated survey effort throughout the Aleutian Island Arc. Over 320 h (4854 km) of visual observations were done during the cruise; ~44% of the effort was during "useable" conditions, i.e., when visibility and sea conditions were appropriate for systematic surveys. A total of 390 individual marine mammals in 149 groups were observed during the cruise. Behavior and density analyses were conducted with "useable" sightings, consisting of 224 individual marine mammals in 101 groups. No injured marine mammals potentially associated with the operations were sighted, and no sea turtles were observed.

Seven different cetacean species were identified during the study and one or more additional species were seen but not identified to the species level. As expected, Dall's porpoise (n = 99 individuals seen) was the most abundant species. A larger than expected number of sperm whales were seen, primarily in an area of local abundance in waters surrounding Buldir Island. This high concentration of

sperm whales was encountered while conducting a portion of the limited seismic surveys performed during the cruise, and thus dramatically increased the "seismic" sighting rate.

The large number of useable sightings (n = 32) made during the very limited seismic periods (~24 hr total), caused primarily by the local abundance of sperm whales near Buldir Island, limits meaningful interpretation of results. The higher detection rate of marine mammals during seismic periods is inconsistent with results from previous seismic surveys. The relatively small sound source used during this study (a single 45 in^3 GI gun) probably resulted in less disturbance to marine mammals as compared with larger airgun arrays used during some previous cruises surveys (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b).

During the Aleutian study, 35 groups involving 63 individuals were seen during seismic operations. One shut down was initiated when a group of Dall's porpoises (seven individuals) was seen approaching the designated safety radius. Based on direct observations, the number of animals estimated to have been exposed to various sound levels was as follows:

- None of the individuals in the single Dall's porpoise group that approached the safety radius were likely to have been exposed to seismic sounds with received levels ***≥180 dB*** re 1 µPa (rms).
- Those same seven Dall's porpoises were observed at a distance where received levels of GI gun sound were estimated to be ***≥170 dB***; and thus also ***≥160 dB***. The 170-dB radius is considered a realistic estimate of the received seismic sound level at which delphinids and Dall's porpoises may be potentially disturbed by seismic sounds .

Densities of marine mammals within the seismic study area were estimated based on "useable" survey data from seismic and non-seismic periods in water depth >100 m. Estimated densities during seismic surveys were ~1.6 to 11 times those during non-seismic periods. Effort was very low during seismic, but the relatively large number of sightings during seismic suggests that densities of marine mammals were higher in the seismic area than in the general area. This was caused by a local abundance of sperm whales encountered during a portion of the very limited amount of seismic surveying performed during the cruise. Therefore, these data do not necessarily suggest that animals moved towards the sound source during periods of seismic survey.

Minimum and maximum estimates of numbers of cetaceans in areas exposed to seismic sounds are shown in Table 4.8 based on the densities estimated from surveys during seismic and non-seismic periods. Also shown, for comparison, are the numbers of "harassment takes" that were requested by L-DEO in the IHA Application. All estimates based on actual density data from non-seismic periods are lower than the "harassment takes" estimated prior to the survey. At most, the estimated number of cetacean exposures to ≥160 dB was ~5% of the maximum estimated in the IHA Application. The number of different individuals exposed was estimated as ~5% of that pre-survey estimate.

Overall, the limited amount of seismic performed during the project resulted in many fewer animals being encountered and disturbed than estimated prior to the cruise. The observations were confirmed that the marine mammal community in the waters surrounding the Aleutian Islands is diverse, with Dall's porpoise and sperm whales being the most abundant species.

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APPENDIX A[2]:
INCIDENTAL HARASSMENT AUTHORIZATION ISSUED TO L-DEO FOR THE SEISMIC PROGRAM IN THE NORTH PACIFIC OCEAN OFF THE ALEUTIAN ISLANDS

DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964-8000, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371 (a)(5)(D)) and 50 CFR 216.107, to harass small numbers of marine mammals incidental to conducting a marine seismic survey program in the North Pacific Ocean off the Aleutian Islands, contingent upon the following conditions:

1. This Authorization is valid from the date of this Authorization through July 10, 2006.

2. This Authorization is valid only for activities associated with the *R/V Thomas G. Thompson* conducting a seismic survey program in the Aleutian Islands area of the North Pacific Ocean off Alaska.

3. (a) The taking, by incidental harassment only, is limited to the species listed under condition 3(b) below. The taking by serious injury or death of these species or the taking by harassment, injury or death of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The species authorized for incidental harassment takings are:

(*i*) Mysticete whales: humpback whale (*Megaptera novaeangliae*), gray whale (*Eschrichtius robustus*), minke whale (*Balaenoptera acutorostrata*), sei whale (*B. borealis*), fin whale (*B. physalus*), and blue whale (*B. musculus*);

(*ii*) Odontocete whales/dolphins: sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), Baird's beaked whale (*Berardius bairdii*), Stejneger's beaked whale (*Mesoplodon stejnegeri*), beluga (*Delphinapterus leucas*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), Risso's dolphin (*Grampus griseus*), killer whale (*Orcinus orca*), short-finned pilot whale (*Globicephala macrorhynchus*), harbor porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*); and

[2] This is a verbatim copy (retyped) of the IHA.

(*iii*) Pinnipeds: Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*) and northern fur seals (*Callorhinus ursinus*), and ribbon seal (*Phoca fasciata*).

(c) The authorization for taking by harassment is limited to the following acoustic sources without an amendment to this Authorization:

(*i*) A seismic airgun with no more than 1-General Injector (GI) airgun operating,
(*ii*) A multi-beam bathymetric sonar (Hydrosweep or Simrad EM300),
(*iii*) A dual-frequency (3.5 and 12 kHz) hydrographic echo sounder (Knudson 320B/R),
(*iv*) A 75-kHz acoustic Doppler current profiler (RDI Ocean Surveyor),
(*v*) An 80-kHz navigational echosounder (Abyss Technologies Model IES-10),
(*vi*) A 200-kHz doppler sonar (Ocean Data Equipment Corporation DSN-450 Mark II), and
(vii) A sub-bottom profiler.

(d) The taking of any marine mammal in a manner prohibited under this Authorization must be reported within 48 hours of the taking to the Chief of the Permits, Conservation and Education Division, Office of Protected Resources, National Marine Fisheries Service, at (301) 713-2289, ext 110, or his designee.

4. The holder of this Authorization is required to cooperate with the National Marine Fisheries Service and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals. The holder must notify the Chief of the Permits, Conservation and Education Division, Office of Protected Resources at least 48 hours prior to starting the seismic survey (unless constrained by the date of issuance of this Authorization in which case notification shall be made as soon as possible).

5. Mitigation. The holder of this Authorization is required to:

(a)(*i*) Establish and monitor the safety zone for cetaceans and sea turtles surrounding the 1-GI airgun where the received level would be 180 dB re 1 µPa rms. This radius is estimated to be 27 m (89 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 41 m (134.5 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 200 m (656 ft) in water depths less than 100 m (328 ft);

(a)(*ii*) Establish and monitor the safety zone for pinnipeds surrounding the 1-GI airgun where the received level would be 190 dB 1 µPa rms. This radius is estimated to be 10 m (33 ft) from the seismic source in water depths 1000 m (3281 ft) or greater, 15 m (49 ft) from the seismic source in water depths of 100-1000 m (328-3281 ft), and 125 m (410 ft) in water depths less than 100 m (328 ft);

(a)(*iii*) Establish and monitor a safety radius of 750 m (2461 ft) surrounding the 1-GI airgun for Steller sea lions whenever the seismic survey is taking place within designated critical habitats, irregardless of the depth of water. Critical habitats in the areas of the survey include 20 nm (37 km) surrounding all haulouts and rookeries as well as the Seguam Pass Foraging Area and Bogoslof Foraging Area.

(b)(*i*) Except for North Pacific right whales, immediately shut-down the GI airgun and/or other acoustic sources, whenever any marine mammals or sea turtles are sighted approaching close to or within the area delineated by the 180 dB (re 1 μPa_{rms}), or 190 dB (re 1 μPa_{rms}) isopleth as established under condition

5(a) for the 1-GI airgun. If any Steller sea lions are found in or seen approaching the 750 m (2461 ft) safety zone within its critical habitat, the airgun will be shut-down.

(b)(*ii*) Shut down the GI-airgun regardless of the distance of the whale from the airgun if a North Pacific right whale is sighted by the vessel-based observers;

(c)(*i*) Not proceed with powering up the 1-GI gun from a shut-down unless the largest appropriate safety zone described in condition 5(a) is visible and no marine mammals or sea turtles are detected within their appropriate safety zones; or until 15 minutes (for small odontocetes, pinnipeds or sea turtles) or a minimum of 30 minutes (for mysticetes/large odontocetes) after there has been no further visual detection of the animal(s) within the safety zone and the trained marine mammal observer on duty is con dent that no marine mammals or sea turtles remain within the appropriate safety zone.

(c)(*ii*) When in designated critical habitat, the 750-m (2461 ft) safety zone will be monitored for Stellar sea lions prior to start-up of the airgun for at least 30 minutes.

(d) Prior to powering up the GI-airgun, conduct a 30-minute period of observation by at least one trained marine mammal observer (*i*) at the commencement of seismic operations and (*ii*) at any time electrical power to the airgun is discontinued for a period of 30 minutes or more.

(e) To the extent practical, whenever a marine mammal is detected outside the safety radius, and based on its position and motion relative to the ship track is likely to enter the safety radius, an alternative ship speed or track will be calculated and implemented.

(f) Emergency shut-down. If observations are made or credible reports are received that one or more marine mammals or sea turtles are within the area of this activity in an injured or mortal state, or are indicating acute distress, the seismic airgun array will be immediately shut down and the Chief of the Permits, Conservation and Education Division, Office of Protected Resources or a staff member contacted. The airgun array will not be restarted until review and approval has been given by the Director, Office of Protected Resources or his designee.

6. Monitoring.

(a) The holder of this Authorization must designate at least three biologically-trained, on-site individuals to be onboard the *R/V Thomas G. Thompson*, approved in advance by the National Marine Fisheries Service, to conduct the visual monitoring program required under this Authorization and to record the effects of seismic surveys and the resulting noise on marine mammals and sea turtles.

(b) Monitoring is to be conducted by the biological observers described in condition 6(a) above, onboard the active seismic vessel. At least one observer must be on active watch whenever the seismic airgun is operating during all daytime airgun operations, during any nighttime power-up of the airgun and at night, whenever monitoring during that day resulted in one or more shut-down situations due to marine mammal presence. To the maximum extent possible two observers will be on watch whenever the seismic airgun is being turned on to (*i*) ensure that no marine mammals or sea turtles enter the appropriate safety zone whenever the seismic airgun is on, and (*ii*) to record marine mammal and sea turtle activity as described in condition 6(f) below.

(c) To the extent possible, observers will be on watch for continuous periods of 4 hours or less.

(d) At all times, the crew must be instructed to keep watch for marine mammals and sea turtles. If any are sighted, the bridge watch-stander must immediately notify the biological observer on watch. If a marine mammal or sea turtle is within, or closely approaching, its designated safety zone, the GI airgun must be immediately powered down.

(e) Observations by the biological observers described in condition 6(a) above on marine mammal presence and activity will begin a minimum of 30 minutes prior to the estimated time that the seismic source is to he turned on.

(f) Monitoring will consist of noting: (*i*) the species, group size, age/size/sex categories (if determinable), the general behavioral activity, heading (if consistent), bearing and distance from seismic vessel, sighting cue, behavioral pace, and apparent reaction of all marine mammals and sea turtles seen near the seismic vessel and/or its airgun array (e.g., none, avoidance, approach, paralleling, etc); (*ii*) the time, location, heading, speed, and activity of the vessel (shooting or not), along with sea state, visibility, cloud cover and sun glare (1) at any time a marine mammal or sea turtle is sighted, (2) at the start and end of each watch, and (3) during a watch (whenever there is a change in one or more variable); and (*iii*) the identification of all vessels that are visible within 5 km of the seismic vessel whenever a marine mammal is sighted, and the time observed, bearing, distance, heading, speed and activity of the other vessel(s).

(g) Biological observers will also conduct monitoring onboard the *R/V Thomas G. Thompson* while the seismic airgun is being deployed or being pulled from the water.

(h) All biological observers must be provided with and use appropriate night-vision devices, Big Eyes, and reticulated an/or laser range finding binoculars.

7. Reporting.

a) A draft report will be submitted to the National Marine Fisheries Service within 90 days after the end of the seismic survey program in Aleutian Islands area off Alaska. The report will describe in detail (*i*) the operations that were conducted, (*ii*) the marine mammals and sea turtles that were detected near the operations, (*iii)* to the extent possible the results of the acoustical measurements to verify the safety radii, and (*iv*) the methods, results, and interpretation pertaining to all monitoring tasks, a summary of the dates and locations of seismic operations, sound measurement data, marine mammal and sea turtle sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential take of marine mammals by harassment or in other ways,

(b) The 90-day draft report will be subject to review and comment by the National Marine Fisheries Service. Any recommendations made by the National Marine Fisheries Service must be addressed in the final report prior to acceptance by the Nation Marine Fisheries Service. The draft report will be considered the final report for this activity under this Authorization if the National Marine Fisheries Service has not provided comments and recommendations within 90 days of receipt of the draft report.

8. Activities related to the monitoring described in this Authorization do not require a separate scientific research permit issued under section 104 of the Marine Mammal Protection Act.

9. The holder of this Authorization is required to fully implement and Terms and Conditions contained in the Biological Opinion issued by the National Marine Fisheries Service for this activity.

10. A copy of this Authorization must be in the possession of the operator of the vessel operating under the authority of this incidental Harassment Authorization.

APPENDIX B:
SAFETY AND DISTURBANCE RADII

This Appendix provides additional background information on the development and implementation of safety radii as relevant to the L-DEO seismic study discussed in this report. Additional information on L-DEO's calibration study conducted with various configurations of airgun arrays is also provided. Further information on these topics can be found in Smultea and Holst (2003), Tolstoy (2004a,b), and the project IHA application and EA (LGL 2004a,b,c).

It is not known whether exposure to a sequence of strong pulses of low-frequency underwater sound from marine seismic exploration actually can cause hearing impairment or non-auditory injuries in marine mammals (Richardson et al. 1995:372*ff*; Finneran et al. 2002). There has been considerable speculation about the potential for injury to marine mammals, based primarily on what is known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). The 180-dB criterion for cetaceans was established by NMFS (1995) based on those considerations, before any data were available on temporary threshold shift (TTS) in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 µPa root-mean-square (rms). The corresponding NMFS criterion for pinnipeds is 190 dB re 1 µPa (rms).

Finneran et al. (2002) have found that the onset of mild TTS in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 µPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$. The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received pressure levels if the animals received a series of pulses. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset.

The above-mentioned 180 dB re 1 µPa level is measured on an rms basis. The rms pressure is an average over the duration of the seismic pulse (Greene 1997; Greene et al. 1998). This is the measure commonly used in recent studies of marine mammal reactions to airgun sounds. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000). Rms level is affected by duration of the received pulse, which depends on propagation effects between the source and the receiving animal. The greater the temporal dispersion of (i.e., the longer) the received pulse, the lower the expected rms level. Biological effects probably are more closely related to energy content of the received pulse than to its rms pressure, but we consider rms pressure because current NMFS criteria are based on that method.

Radii within which received levels were expected to diminish to various values relevant to NMFS criteria mentioned above were determined by L-DEO based on a combination of acoustic modeling and empirical measurements. Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 in^3 GI (generator injector) guns, a 20-airgun array (the largest array deployed during L-DEO seismic surveys), and various intermediate-sized airgun arrays. The empirical data were collected in the Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b).

The rms received levels in the near field around various airgun configurations used by L-DEO have also been predicted based on a L-DEO model. Figure B.1 shows the predicted sound field for 1 GI gun with a volume of 105 in^3, on which the safety radii for the Aleutian study were based. The GI gun actually used during the Aleutian study had a generator volume of 45 in^3, and therefore the assumed

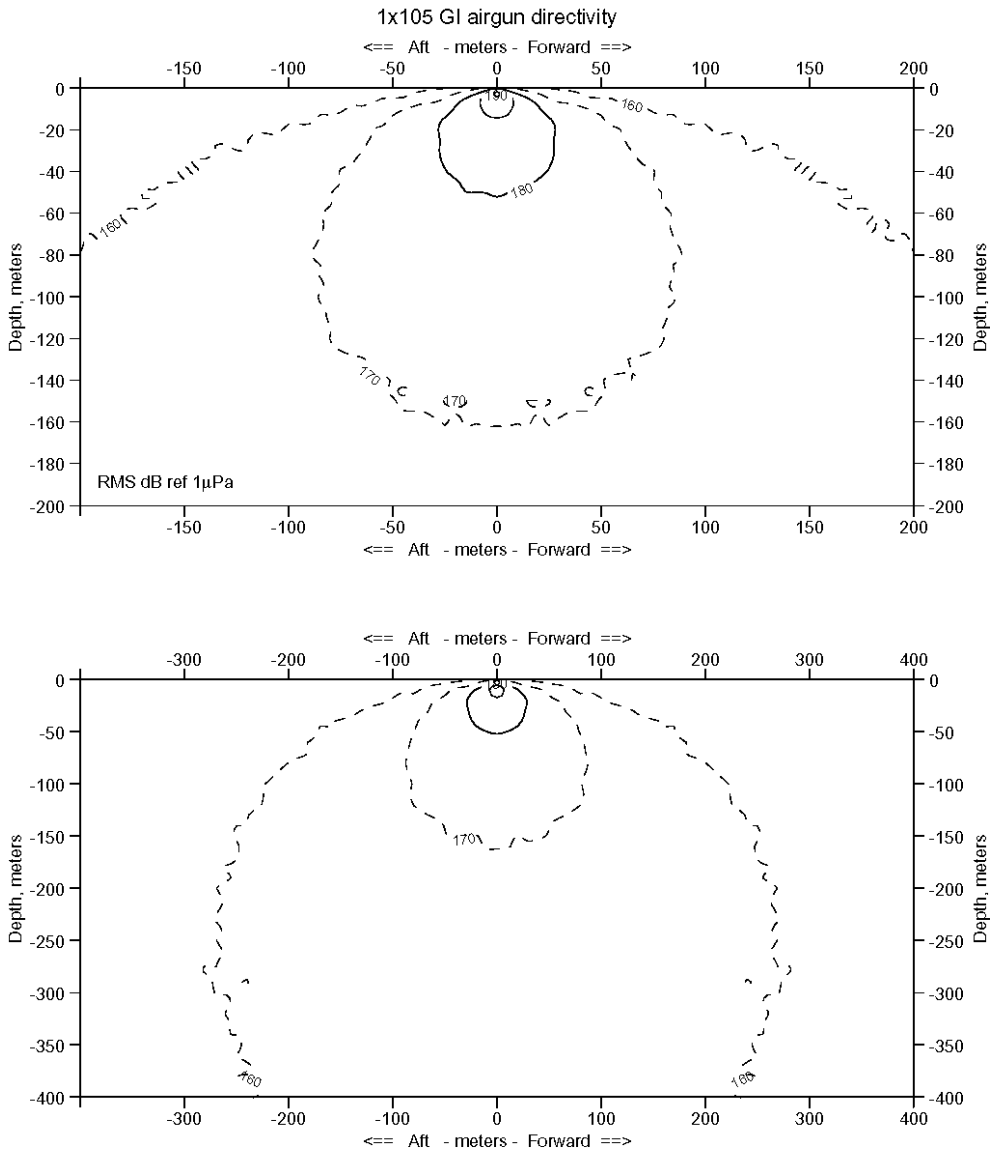

FIGURE B.1. Modeled received sound levels from one 105 in^3 GI gun. The generator volume of the actual GI gun used during the Aleutian study was 45 in^3, and therefore distances presented here are ~33% larger than actually occurred. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations.

safety and disturbance radii were ~33% larger than necessary for this smaller sound source. "Takes" were correspondingly overestimated. The sound fields shown in Figure B.1 pertain primarily to deep water, and the model does not allow for bottom interactions.

For mitigation purposes during L-DEO studies, three strata of water depth are distinguished: shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m). The calibration study showed that sounds from L-DEO's larger airgun sources (i.e., 6–20 airguns) operating in deep water tended to have lower received levels than estimated by the model. In other words, the model tends to overestimate the actual distances at various sound levels in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study relevant to this and other recent projects are summarized below:

- Empirical measurements were not made for a single small source operating in ***shallow water*** (<100 m). However, the measured 180 dB radius for the 6-airgun array operating in shallow water was 6.8x that predicted by L-DEO's model for operation of the 6-airgun array in deep water. This conservative correction factor was used to predict the radii for two GI guns. The radii for one GI gun were assumed to be half of those for the two GI guns.
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results will be intermediate between those from shallow and deep water, a 1.5x correction factor is applied to the estimates provided by the model for deep water situations. This is the same factor that was applied to the model estimates during L-DEO cruises in 2003.
- The empirical data indicate that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be precautionary pending acquisition of additional empirical data, safety radii used during GI gun operations in deep water have been the values predicted by L-DEO's model (Table 3.1).

For sea turtles, NMFS specified a 180-dB radius for the project. This was the same safety criterion applied to sea turtles during both L-DEO's spring 2004 Southeast Caribbean seismic survey and fall 2004 Blanco survey conducted from the *Ewing* (Smultea et al. 2004).

The radius at which received levels diminish to 160 dB re 1 μPa (rms) is considered by NMFS to be a possible criterion of behavioral disturbance for cetaceans. The data on which this 160 dB criterion is based pertain to baleen whales, and many of the odontocetes (e.g., delphinids) do not appear to be as responsive to seismic sounds as are baleen whales (Richardson et al. 1995; Gordon et al. 2004). In this report, the numbers of all species exposed to ≥160 dB are estimated. However, for certain taxa (e.g., delphinids, Dall's porpoises, pinnipeds), the 170 dB radius is considered as an alternative and more realistic estimate of the outer bounds of the area within which animals are likely to have been disturbed significantly. For those taxa, the numbers exposed to ≥170 dB are also estimated.

APPENDIX C:
DESCRIPTION OF R/V *THOMAS G. THOMPSON* AND EQUIPMENT USED DURING THE PROJECT

This appendix provides a detailed description of the equipment used during this L-DEO seismic and rock dredging study aboard the R/V *Thomas G. Thompson.*

R/V Thomas G. Thompson *Vessel Specifications*

L-DEO used the R/V *Thomas G. Thompson* for the seismic study to tow the single GI gun and hydrophone streamer (Fig. C.1). The *Thompson* was self-contained, with the crew living aboard the vessel. The *Thompson* has a length of 83.5 m, a beam of 16 m, and a full load draft of 5.8 m. The ship is powered by three 1500-kW CAT/KATO motors and is equipped with twin 360° azimuth stern thrusters rated at 3000 HP each and an 1100 HP water-jet bow thruster. Three CAT/KATO 715-kW generators supply power to the ship. The operation speed during seismic acquisition was 11 km/h (6 knots). When not towing seismic survey gear, the *Thompson* cruises at 22 km/h (12 kt) and has a maximum speed of 26.9 km/h (14.5 kt). It has a normal operating range of ~24,400 km.

Other details of the *Thompson* include the following:

Owner:	U.S. Navy
Operator:	University of Washington
Flag:	United States of America
Date Built:	8 July 1991
Gross Tonnage:	3250 LT
Echosounders:	Simrad EM300 multi-beam, Knudsen 320BR Echosounder, Hydrosweep multi-beam, EIS-10 Navigational Echosounder
Acoustic Doppler Current Profiler	RDI 75 kHz Ocean Surveyor
Compressors for Airguns:	2 × LMF DC, capable of 175 scfm at 2000 psi
Accommodation Capacity:	60 including 36 scientists

The *Thompson* also served as the platform from which vessel-based marine mammal observers (MMOs) watched for mammals and sea turtles. Two locations were used as MMO stations onboard the *Thompson*. The bridge was used as the primary observation station where visibility was ~310° for one observer and a full 360° for two observers. The second observation station used was the 03 deck where visibility was ~330° for two observers (Fig. C.1, C.2).

Multibeam Sonar, Sub-bottom Profiler, and Echosounder

Along with the GI gun operations, four additional acoustic systems operated during the cruise. A 30-kHz MBB sonar (Simrad EM300) operated throughout most of the cruise to map the bathymetry and identify dredge targets. A 15.5-kHz Hydrosweep MBB sonar (Krupp-Atlas Elektroniks Hydrosweep DS) was used only once during surveys in very deep waters over Murray Canyon southwest of Kiska Island. The navigational echosounder or fathometer (Abyss Technologies, Inc. Model IES-10) was also used only once while conducting bathymetric surveys in very shallow waters just east of Seguam Island. This type of sonar is routinely employed by sea-going vessels to monitor water depths. A 12-kHz pinger

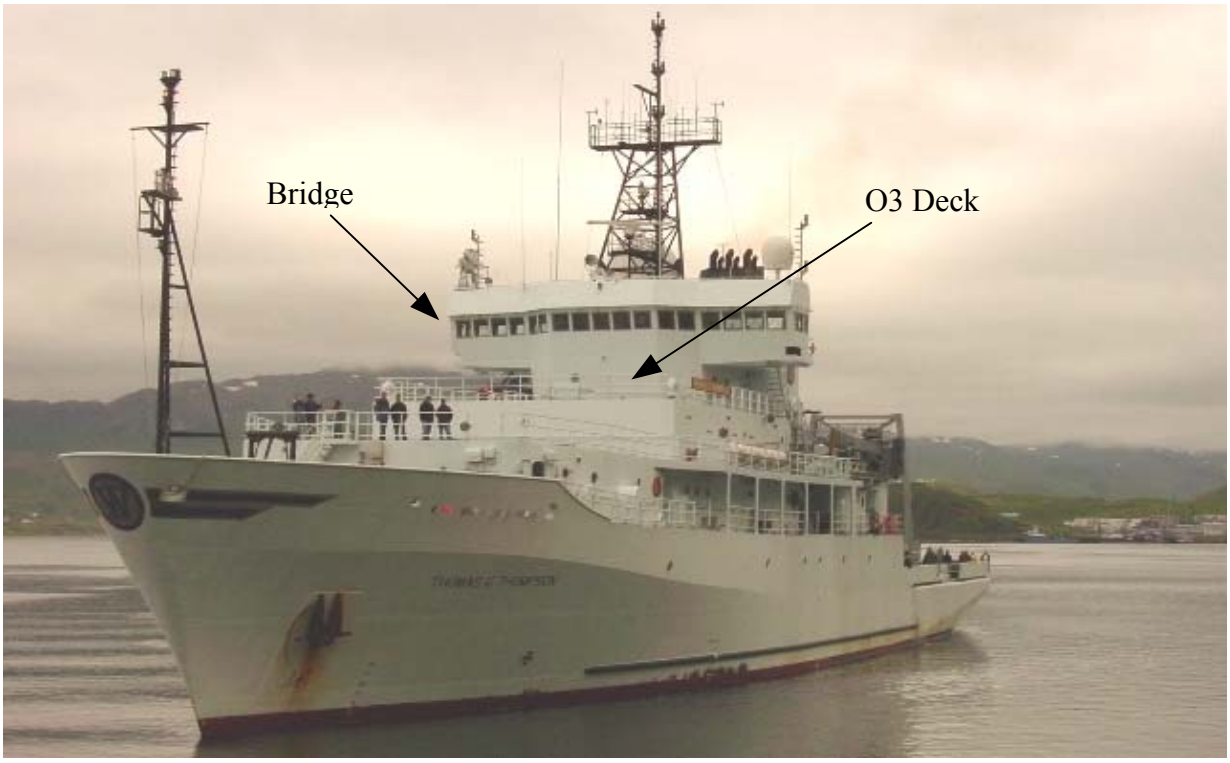

FIGURE C.1. The source vessel, the R/V *Thomas G. Thompson,* showing the location of the bridge and O3 deck from which visual observations were made by the marine mammal observers.

FIGURE C.2. A view of the O3 deck of the *Thompson* showing the visual observer station and associated equipment, including the mounted 25x150 “Big-eye” binoculars used during the study.

was used during most dredging operations over 750 m in depth (~50 dredges). During seismic operations, the 30-kHz echosounder was the only device operated simultaneously with the GI gun.

Multibeam Echo Sounder Sonar (Simrad EM300)

A Simrad EM300 30-kHz multibeam sonar was the primary bottom-mapping sonar during this cruise. The Simrad EM300 transducer is hull mounted within a transducer pod that is located midship. The system's normal operating frequency is 30 [DI9]kHz. The transmit fan is split into either three or nine narrower beam sectors with independent active steering to correct for vessel yaw. Angular coverage is 36° (in Extra Deep Mode, at 3000 to 6000 m) or 150° (in shallower water). The total angular coverage of 36° or 150° consists of the 3 or 9 beams transmitted at slightly different frequencies. The sectors are frequency coded between 30 and 34 kHz and they are transmitted sequentially at each ping. Except in very deep water where the beam is 36° × 1°, the fan beam is 150° × 1°, 150° × 2° or 150° × 4° depending on water depth. These beams overlap slightly if the vessel yaw is less than the fore-aft width of the beam (1, 2 or 4° respectively). Achievable swath width on a flat bottom will normally be ~5× the water depth.

In deep water a pulse length of 5 ms is normally used. For the greatest depths, an Extra Deep mode is available using a pulse length of 15 ms. In the Extra Deep mode the coverage is limited to 36°. This results in a swath width of 2–3 km for depths exceeding 4000 m. At intermediate depths a pulse length of 2 ms is used and in shallow water a pulse length of 0.7 ms is used. The ping rate is mainly limited by the round trip travel time in the water up to a ping rate of 10 pings/s in shallow water.

Multibeam Echosounder (Krupp-Atlas Elektroniks Hydrosweep DS)

The Krupp-Atlas Hydrosweep multibeam was used in deep waters where it performs better than the Simrad EM300 system. The Hydrosweep system is a multibeam sweeping echosounder operating at a frequency of 15.5 kHz with a cross-track angular coverage of 90° and narrow fore-aft beamwidth. Maximum depth range is 10,000 m with a source level of 237 dB re 1 µPa-m.

Hydrographic Echosounder (Knudsen 320BR)

The 320BR echosounder is a dual–frequency system with operating frequencies of 3.5 and 12 kHz. Pulse lengths up to 24 ms and bandwidths to 5 kHz are available. Maximum output power at 3.5 kHz is 10 kW and at 12 kHz it is 2 kW.

Navigational Echosounder (Abyss Technologies, Inc. Model IES-10)

This navigational echosounder's operating frequency is 80 kHz and it operates with a maximum output power of 1 kW.

12-kHz Pinger (Benthos 1216)

A Benthos 12-kHz pinger was used only during scientific rock dredging operations to monitor the depth of the dredge relative to the sea floor. The pinger is a battery-powered acoustic beacon that is attached to the rock dredging mechanism. The pinger produces an omnidirectional 12 kHz signal with a source output of ~192 dB re 1 µPa-m at a one pulse per second rate. The pinger produces a single pulse of 0.5, 2 or 10 ms duration (hardware selectable within the unit) every second.

APPENDIX D:
DETAILS OF MONITORING, MITIGATION, AND ANALYSIS METHODS

This appendix provides details on the standard visual monitoring methods and data analysis techniques implemented for this project and previous L-DEO seismic studies.

Résumés documenting the qualifications of the MMOs were provided to NMFS prior to commencement of the study. All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA stipulations. In addition, implementation of the IHA requirements was explained to the Captain, Science Officer, Head Airgun Operator, and Science Party PIs aboard the vessel. MMO duties included

- watching for and identifying marine mammals and sea turtles, and recording their numbers, distances and behavior;
- noting possible reactions of marine mammals and sea turtles to the seismic operations;
- initiating mitigation measures when appropriate; and
- reporting the results.

Visual Monitoring Methods

Visual watches took place in the survey area and during transits to and from the study area. In addition to conducting watches during seismic operations, MMOs also watched during the daytime when the source vessel was underway but the GI gun was not in use. This included ***(1)*** periods during transit to and from the seismic survey area, ***(2)*** a short "pre-seismic period" while equipment was being deployed, ***(3)*** periods when the seismic source stopped firing while equipment was being repaired, and ***(4)*** a short "post-seismic" period.

Visual observations were generally made from the bridge (Fig. C.1), the highest suitable vantage point on the vessel. The observer's eye level was ~13.8 m (45 ft) above sea level. The bridge afforded a view of ~310º centered on the front of the *Thompson*, with partial obstructions to the stern. With two or more observers, one stationed on the port and one on the starboard side of the vessel, the partial obstruction was significantly reduced. MMOs observed from the 03 deck during periods of fair weather. The observer's eye level on the 03 deck was ~10.8 m (35 ft) above sea level, with a field of view of ~330º.

A total of three observers trained in marine mammal identification and observation methods were present on the vessel during the study. Visual watches were usually conducted in 2–3 h shifts (max. 4 h), alternating with 1–4 h breaks, for a total of ~9 h per day per MMO during full-operation days. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Occasionally scans were also made using the 25×150 Big-eye binoculars, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one MMO, and if possible two MMOs, were on duty, especially during the 30 min before, and then during seismic surveys. Nighttime observations were conducted only on occasions when a shut down of seismic operations had occurred during the previous day due to the presence of a marine mammal within the applicable safety radius.

When MMO(s) were not on active duty, the bridge personnel were asked to watch for marine mammals and turtles during their regular watches. They were provided with a copy of the observer instruction manual and marine mammal identification guides that were kept on the bridge. If the bridge

crew sighted marine mammals or sea turtles at night, they were given instructions on how to fill out specific marine mammal and sea turtle sighting forms in order to collect pertinent information on sightings when MMOs were not on active duty. Bridge personnel would also look for marine mammals and turtles during the day, when MMO(s) were on duty.

While on watch, visual observers kept systematic written records of the vessel's position and activity, and environmental conditions. Codes that were used for this information are shown in Table D.1. Watch data were entered manually onto a datasheet every ~30 min, as activities allowed. Additional data were recorded when marine mammals or sea turtles were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well.

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table D.1. Distances to groups were estimated from the MMO's location, rather than from the nominal center of the seismic source (the distance from the sighting to the seismic source was calculated during analyses). However, for sightings near or within the safety radius in effect at the time, the distance from the sighting to the GI gun was estimated and recorded for the purposes of implementing shut downs. The bearing from the observation vessel to the nearest member of the group was estimated using positions on a clock face, with the bow of the vessel taken to be 12 o'clock and the stern at 6 o'clock.

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every minute by the navigation system. Those data were used when detailed position information was required. In addition, the following information was recorded, if possible, for other vessels within 5 km (as specified in the IHA) at the time of a marine mammal sighting: vessel type, size, heading (relative to study vessel), bearing (relative to study vessel), distance, and activity.

All data were initially recorded on datasheets in the field and were entered into a Microsoft Excel® database at the end of the day. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computerized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers, and manually against the geologists' project logs.

Mitigation

Start-up and shut-down procedures, which are described briefly in Chapter 3, are described in detail below. These were the primary forms of mitigation implemented during seismic operations.

Start-up Procedures

A "start-up" procedure was followed at the commencement of seismic operations with the GI gun, and anytime after the gun was shut down for a specified duration. Under normal operational conditions (vessel speed 6 kt), start-up procedures were conducted after a shut down lasting 8 min or longer.

TABLE D.1. Summary of data codes used during the seismic survey.

WS	Watch Start
WE	Watch End

LINE
Enter Line ID or leave blank

SEISMIC ACTIVITY

RU	Ramp-up
LS	Line Shooting
TR	Transiting @ < 2 kt
MI	Ship milling/stopped
DP	Deploying OBSs
RC	Recovering OBSs
SH	Shooting Between/Off Lines
ST	Seismic Testing
SZ	Safety Zone Shut-Down
PD	Power-Down
SD	Shut-Down
OT	Other (comment and describe)

 # GUNS
Enter Number of Operating Airguns, or

88	Varying (e.g., ramp-up)
99	Unknown

ARRAY VOLUME
Enter operating volume, or

99	Unknown

(BEAUFORT) SEA STATE
See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION
Clock Position, or

99	Variable (vessel turning)

WATER DEPTH
In meters

MARINE MAMMAL SPECIES

Baleen Whales

BLW	Blue Whale
BRW	Bryde's Whale
FW	Fin Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale

Large Toothed Whales

DSW	Dwarf Sperm Whale
FKW	False Killer Whale
KW	Killer Whale
MHW	Melon-headed Whale
PKW	Pygmy Killer Whale
PSW	Pygmy Sperm Whale
SPW	Sperm Whale
SFPW	Short-finned Pilot Whale
UTW	Unidentified Tooth Whale

Beaked Whales

BBW	Blainville's Beaked Whale
CBW	Cuvier's Beaked Whale
GBW	Gervais' Beaked Whale
SBW	Sowerby's Beaked Whale
UBW	Unidentified Beaked Whale

Dolphins

ASD	Atlantic Spotted Dolphin
BD	Bottlenose Dolphin
CD	Clymene Dolphin
FD	Fraser's Dolphin
LCD	Long-beaked Common Dolphin
PSP	Pantropical Spotted Dolphin
RD	Risso's Dolphin
RTD	Rough-toothed Dolphin
SCD	Short-beaked Common Dolphin
SPD	Spinner Dolphin
STD	Striped Dolphin
UD	Unidentified Dolphin

Pinnipeds

HDS	Hooded Seal

TURTLE SPECIES

GR	Green Turtle
HB	Hawksbill Turtle
KR	Kemp's Ridley Turtle
LH	Loggerhead Turtle
LB	Leatherback Turtle
UT	Unidentified Turtle

MOVEMENT

PE	Perpendicular across bow
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
NO	No movement
UN	Unknown

INDIVIDUAL BEHAVIOR

MA	Mating
SI	Sink
FD	Front Dive
TH	Thrash Dive
DI	Dive
LO	Look
LG	Logging
SW	Swim
BR	Breach
LT	Lobtail
SH	Spyhop
FS	Flipper Slap
FE	Feeding
FL	Fluking
BL	Blow
BO	Bow Riding
PO	Porpoising
RA	Rafting
WR	Wake Riding
AG	Approaching Guns
DE	Dead
OT	Other (describe)
NO	None (sign seen only)
UN	Unknown

GROUP BEHAVIOR (BEHAVIORAL STATES)

TR	Travel
SA	Surface Active
ST	Surface Active-Travel
MI	Milling
FG	Feeding
RE	Resting
OT	Other (describe)
UN	Unknown

 # RETICLES or ESTIMATE
(of Initial Distance, etc.; Indicate Big eyes or Fujinons in comments)

0 to 16	Number of reticles
E	Estimate, by eye

SIGHTING CUE

BO	Body
HE	Head
SP	Splash
FL	Flukes
DO	Dorsal Fin
BL	Blow
BI	Birds

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

WITH ABOVE RECORD?

Y	Yes
(blank)	not with above record

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during start up. The IHA also specified that the start up could only commence if no marine mammals or sea turtles were detected within the safety radius during this period. Start-up of the GI gun was not permitted at night unless the entire area of the largest of the then-applicable safety zones was visible.

Shut-down Procedures

The GI gun was immediately shut down when one or more marine mammals or sea turtles were detected within, or judged about to enter, the applicable safety radius (see Table 3.1 in Chapter 3).

The shut-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal or sea turtle was within or about to enter the safety radius. Seismic operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (15 min for dolphins, 25 min for turtles, and 30 min for whales). Once the safety radius was judged to be clear of marine mammals or sea turtles based on those criteria, the MMO advised the gun operators and geophysicists, who advised the bridge that seismic surveys could re-commence, and start-up was initiated. The MMOs were stationed on the bridge or 03 deck about 67 m ahead of the GI gun; located ~25 m aft of the stern. The decision to initiate a shut-down was based on the distance from GI gun because the only marine mammal sighting during seismic operations occurred off the stern of the vessel.

Analyses

This section describes the analyses of the marine mammal sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities and estimate the number of marine mammals potentially exposed to seismic sounds associated with the seismic survey. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (GI gun operating with shot spacing <90 s) and "non-seismic" categories (periods before seismic started or >2 h after the GI gun was turned off). The analyses excluded the "post-seismic" period 90 s to 2 h after the GI gun was turned off. The justification for the selection of these criteria is based on the size of the airgun source in use and is provided below; these criteria were previously discussed in earlier L-DEO cruise reports to NMFS (see Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b).

- The period up to 90 s after the last seismic shot is ~10× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- It is likely that any marine mammals near the vessel between 90 s and 30 min after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 30 min) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the marine mammals may still be influenced by the (previous) sounds.
- For some unknown part of the period from 30 min to 2 h post-seismic, it is possible that the distribution of the animals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds.
- By 2 h after the cessation of seismic operations, the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and thus

the MMOs. Given those considerations, plus the limited observed responses of most marine mammals to seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b), it is unlikely that the distribution or behavior of marine mammals near the vessel >2 h post-seismic would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >2 h after cessation of seismic operations to be unaffected by the (previous) seismic sounds.

As summarized in Chapter 3, marine mammal density was one of the parameters examined to assess differences in the distribution of marine mammals relative to the seismic vessel between seismic and non-seismic periods. Line transect procedure for vessel-based visual surveys were followed. To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using approximate correction factors derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without the use of correction factors at all.

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. As standard for line-transect estimation procedures, densities were corrected for the following two parameters before they were further analyzed:

- $g(0)$, a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along the trackline are detected.
- $f(0)$, the reduced probability of detecting an animal with increasing distance from the track-line.

The $g(0)$ and $f(0)$ factors used in this study were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on $f(0)$ based on group size. Further, this type of project cannot provide data on $g(0)$. Estimates of these correction factors were derived from Koski et al. (1998) and Barlow (1999), for corresponding species and Bf. Marine mammal sightings were subjected to species-specific truncation criteria obtained from the above studies.

Number of Exposures.—Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the following three values:

- number of kilometers of seismic survey,
- width of the area assumed to be ensonified to ≥160 dB (2 × 160 dB radius) in each water depth, as associated with the Aleutian cruise (Table 3.1), and
- "corrected" densities of marine mammals estimated by line transect methods as summarized above.

Number of Individuals Exposed.—The estimated number of individual exposures to levels ≥160 dB obtained by the method described above likely overestimates the number of different *individual* mammals exposed to the airgun sounds at received levels ≥160 dB. During this cruise, the number of individuals exposed is similar to the number of exposure incidents because seismic lines were not closely spaced (see Fig. 4.1).

A minimum estimate of the number of different individual marine mammals potentially exposed (one or more times) to ≥160 dB re 1 µPa (rms) was calculated. That involved multiplying the corrected density of marine mammals by the area exposed to ≥160 dB one or more times during the course of the

study. The area was calculated using MapInfo Geographic Information System (GIS) software by creating a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with the water depth, the width of the buffer also varied with water depth (Table D.2). The buffer includes areas that were exposed to airgun sounds ≥160 dB one or more times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). The buffer area only counts the repeated-coverage areas once, as opposed to the "exposures" method outlined above. The calculated number of different individual marine mammals exposed to ≥160 dB re 1 μPa (rms) is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The buffer process outlined above was repeated for delphinids, Dall's porpoises, and pinnipeds, assuming that for those animals, the estimated 170 dB radius (see Table 3.1) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 μPa (rms). The process was also repeated for all marine mammal species based on the estimated 180-dB radius. That was done to estimate the numbers of animals that would have been subjected to sounds with received levels ≥180 dB re 1 μPa (rms) if they had not altered their course to avoid those sound levels (or the ship).

TABLE D.2. The areas (km^2) potentially ensonified to various levels by the GI gun operating in two water depth strata within the study area (intermediate depths, 100–1000 m, and deep, >1000 m) during seismic periods of the Aleutian cruise, 23 July–20 Aug. 2005. ***(A)*** Maximum area ensonified, with overlapping areas counted multiple times. ***(B)*** Total area ensonified at least once, with overlapping areas counted only once.

	Water Depth 100 - 1000 m				Water Depth >1000 m				
Area (km^2)	160 dB	170 dB	180 dB	190 dB	160 dB	170 dB	180 dB	190 dB	Total
A. Including Overlap Area	151.7	47.8	14.3	5.2	205.1	66.2	19.7	7.3	517.3
B. Excluding Overlap Area	151.7	47.8	14.3	5.2	203.7	66.0	19.7	7.3	515.7

APPENDIX E:
MARINE MAMMALS IN THE ALEUTIAN ISLANDS

TABLE E.1. The habitat, abundance, and conservation status of marine mammals that are known to occur in the Aleutian Islands.

Species	Habitat	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes						
Sperm whale (*Physeter macrocephalus*)	Pelagic, deep seas	159 [9]	24,000 [4]	Endangered*	VU	I
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	N.A.	20,000 [5] 1884 [6]	Not listed	DD	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	N.A.	6000 [7] 228 [6]	Not listed	LR-cd	I
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Likely pelagic	N.A	N.A	Not listed	DD	II
Beluga whale (*Delphinapterus leucas*)	Coastal, ice edges	1619 [11] 435 [12]	N.A.	Not listed	VU	II
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Offshore/ inshore	26,880 [8]	59,274 [6]	Not listed	LR-lc	II
Risso's dolphin (*Grampus griseus*)	Offshore/in-shore, >400m	N.A.	16,066 [6]	Not listed	DD	II
Killer whale (*Orcinus orca*)	Widely distributed	1472 [9]	1340 [6]	Not listed	LR-cd	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Inshore and offshore	N.A.	160,200 [5] 304 [6]	Not listed	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal, inland waters	47,356 [14]	39,586 [10]	Not listed	VU	II
Dall's Porpoise (*Phocoenoides dalli*)	Shelf and pelagic	30,248 [9]	98,617 [6] 417,000 [13]	Not listed	LR-cd	II
Mysticetes						
North Pacific right whale (*Eubalaena japonica)*	Coastal and shelf	N.A.	<100 [15]	Endangered*	EN	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	N.A.	26,635 [16]	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore and banks	2036 [18] 4005 [19] 2866 [9]	>6000 [17]	Endangered*	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	1512 [9]	1015 [6] 810-1003 [20]	Not listed	LR-cd	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	N.A.	7260-12,620 [21,22] 56 [6]	Endangered*	EN	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	N.A.	8520-10,970 [21,23] 3279 [6]	Endangered*	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	N.A.	1400-1900 [24] 3000 [25]	Endangered*	EN	I

Species	Habitat	Abundance (Alaska)	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Pinnipeds						
Northern fur seal (*Callorhinus ursinus*)	Pelagic, breeds coastally	N.A.	888,120 [26]	Not listed but depleted	VU	N.A.
California sea lion (*Zalophus californianus*)	Coastal, shelf	N.A.	244,000-237,000 [27]	Not listed	NA	NA
Steller sea lion (*Eumetopias jubatus*)	Coastal	34,779 [13]	31,028 [26]	Threatened† Endangered‡	EN	N.A.
Pacific Walrus (*Odobenus rosmarus divergens*)	Ice	N.A.	201,039 [28]	Not listed	N.A.	N.A.
Bearded seal (*Erignathus barbatus*)	Ice	N.A.	300,000 [29]	Not listed	N.A.	N.A.
Harbor seal (*Phoca vitulina richardsi*)	Coastal	29,175 [30]	N.A.	Not listed	N.A.	N.A.
Spotted seal (*Phoca largha*)	Ice	N.A.	250,000 [31]	Not listed	N.A.	N.A.
Ringed seal (*Pusa hispida*)	Ice	N.A.	Up to 3.6 million [32]	Not listed	N.A.	N.A.
Ribbon seal (*Histriophoca fasciata*)	Ice	N.A.	100,000 [33]	Not listed	N.A.	N.A.
Northern elephant seal (*Mirounga angustirostris*)	Coastal, pelagic when migrating	N.A.	101,000 [34]	Not listed	NA	NA.
Fissipeds						
Sea otter (*Enhydra lutris*)	Coastal	8742 [35] 41,474 [36]	N.A.	Proposed threatened	EN	II

N.A. means data not available.

[1] Endangered Species Act

[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).

[4] Abundance estimate for eastern temperate North Pacific (Whitehead 2002).

[5] Abundance in the Eastern Tropical Pacific (Wade and Gerrodette 1993).

[6] Abundance off California/Oregon/Washington (Barlow 2003).

[7] Abundance in Western North Pacific (Reeves and Leatherwood 1994).

[8] Abundance estimate for GOA (Buckland et al. 1993).

[9] Northern GOA and Aleutian Islands (Zerbini et al. 2004).

[10] Oregon/Washington stock (Carretta et al. 2004).

[11] Bristol Bay stock (Angliss and Lodge 2004).

[12] Abundance estimate for Cook Inlet stock (Hobbs et al. 2000).

[13] Abundance estimate for western stock (Angliss and Lodge 2004).

[14] Abundance estimate for Bering Sea stock (Angliss and Lodge 2004).

[15] Eastern populations (Carretta et al. 2002).

[16] Abundance estimate for eastern Pacific (Hobbs and Rugh 1999).

[17] North Pacific (Calambokidis and Barlow 2004).

[18] All feeding aggregations (Angliss and Lodge 2004).

[19] Abundance estimate for the central North Pacific stock (Calambokidis et al. 1997).

[20] Abundance estimate for Bearing Sea (Moore et al. 2002).

[21] USWC (Carretta et al. 2004).

[22] Abundance in NPO (Tillman 1977).

[23] Abundance in NPO (Ohsumi and Wada 1974).

[24] Abundance in NPO (Klinowska 1991).

[25] Abundance for California/Oregon/Washington (Calambokidis and Barlow 2004).

[26] Abundance for eastern NPO or eastern stock (Angliss and Lodge 2004).
[27] Abundance estimate for SE Alaska stock (Angliss and Lodge 2004).
[28] Estimate for population in 1990 (Gilbert et al. 1992 *in* Angliss and Lodge 2004); current size unknown.
[29] Estimate for Bering Sea (Burns 1981a); current estimate is unavailable.
[30] Abundance estimate for the GOA stock (Angliss and Lodge 2004).
[31] Estimate for Bering Sea (Burns 1973); current estimate is unavailable.
[32] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).
[33] Estimate for Bering Sea (Burns 1981b); current estimate is unavailable.
[34] California Breeding Stock (Carretta et al. 2004)
[35] Aleutian Islands (Doroff et al. 2003).
[36] Abundance estimate Southwest Alaska stock (Angliss and Lodge 2004).
* Listed as a strategic stock under the U.S. Marine Mammal Protection Act.
† Eastern stock; listed as a strategic stock under the U.S. Marine Mammal Protection Act.
‡ Western stock; listed as a strategic stock under the U.S. Marine Mammal Protection Act.

APPENDIX F:
OBSERVATION EFFORT AND SIGHTINGS

TABLE F.1. All and useable[a] observation effort from the vessel during the Aleutian cruise, 20 July–20 Aug. 2005, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by water depth and GI gun status.

	All Effort			Useable[a] Effort			
Water Depth (m)	<100	100-1000	>1000	<100	100-1000	>1000	Total
(A) Effort in h							
Seismic	0	13	30	0	4	5	52
Post Seismic	0	2	8	N/A	N/A	N/A	10
Non-Seismic	33	359	299	6	59	82	838
Total	33	374	337	6	63	87	900
(B) Effort in km							
Seismic	0	173	365	0	54	63	655
Post-Seismic	0	22	105	N/A	N/A	N/A	127
Non-Seismic	108	4029	4394	78	982	1661	11252
Total	108	4224	4864	78	1036	1724	12034

[a] Useable detections are those made during useable daylight visual observations as defined in *Acronyms and Abbreviations*.

TABLE F.2. All and useable[a] observation effort from the vessel within the Aleutian Islands study area, 20 July–20 Aug. 2005, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by Beaufort Wind Force and GI gun status.

	All Effort							Useable[a] Effort					Total	
Beaufort Wind Force	1	2	3	4	5	6	7	1	2	3	4	5	Useable	Total
(A) Effort in h														
Seismic	8	8	2	0	0	8	4	7	0	1	0	0	8	30
Post Seismic[b]	0	4	2	0	0	1	1	N/A	N/A	N/A	N/A	N/A	N/A	8
Non-Seismic	20	57	107	56	30	15	4	8	21	45	24	7	105	289
Total	28	69	111	56	30	24	9	15	21	46	24	7	113	327
(B) Effort in km														
Seismic	94	89	31	0	0	22	45	90	5	15	0	0	110	281
Post Seismic[b]	0	42	32	0	0	6	19	N/A	N/A	N/A	N/A	N/A	N/A	99
Non-Seismic	292	806	1767	1001	353	199	57	145	393	886	509	99	2032	4475
Total	386	937	1830	1001	353	227	121	235	398	901	509	99	2142	4855

[a] Useable detections are those made during useable daylight visual observations as defined in *Acronyms and Abbreviations*.

TABLE F.3. Sightings made from the *Thompson* during the Aleutian survey (including transits), 20 Jul.–20 Aug. 2005; all sightings made during daylight hours.

Species	Useable (Y) or Non-Useable (N)[a]	Group Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (- =°W + =°E)	Initial Sighting Distance from GI Gun (m)	CPA[b] Distance from GI Gun (m)	Initial Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)	Vessel Activity[f]	Gun On or Off[g]	Mitigation Done[h]
Unidentified Dolphin/Porpoise	Y	8	21-Jul	3:01:34	54.000	-166.554	644	644	SP	PO	2	100-1000	OT	Off	None
Humpback Whale	Y	3	21-Jul	3:11:35	54.029	-166.592	1196	1042	SP	SW	2	100-1000	OT	Off	None
Unidentified Whale	Y	1	21-Jul	3:50:57	54.025	-166.828	5376	5376	UN	BR	3	100-1000	OT	Off	None
Unidentified Dolphin/Porpoise	Y	8	21-Jul	19:49:06	53.601	-172.290	166	166	SP	PO	4	>1000	OT	Off	None
Minke Whale	N	2	21-Jul	20:07:52	53.591	-172.400	720	720	MI	MI	4	>1000	OT	Off	None
Minke Whale	Y	1	21-Jul	20:28:30	53.584	-172.521	1296	1296	SP	SW	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	2	21-Jul	20:39:24	53.580	-172.586	2770	2770	SP	TR	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	2	21-Jul	21:03:31	53.571	-172.729	1007	1007	SP	TR	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	2	21-Jul	21:23:17	53.563	-172.847	3958	3958	SP	TR	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	1	21-Jul	21:46:43	53.552	-172.985	1228	1228	SP	SW	4	>1000	OT	Off	None
Fin Whale	Y	3	21-Jul	21:53:02	53.549	-173.024	1767	1767	PE	TR	4	>1000	OT	Off	None
Minke Whale	Y	3	21-Jul	22:27:00	53.536	-173.230	1070	1070	SP	TR	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	2	22-Jul	0:58:31	53.478	-174.152	1007	1007	UN	BL	3	>1000	OT	Off	None
Fin Whale	Y	1	22-Jul	2:02:32	53.441	-174.526	3342	3342	UN	BL	3	>1000	OT	Off	None
Killer Whale	Y	2	22-Jul	4:10:15	53.385	-175.243	122	122	ST	SW	4	>1000	OT	Off	None
Unidentified Mysticete Whale	Y	1	22-Jul	19:42:00	53.041	179.419	1556	1556	SP	BL	4	>1000	OT	Off	None
Unidentified Dolphin/Porpoise	Y	7	23-Jul	6:22:16	52.783	175.737	404	404	SP	TR	3	>1000	OT	Off	None
Unidentified Dolphin/Porpoise	Y	5	23-Jul	7:13:09	52.760	175.427	408	408	SP	PO	3	>1000	OT	Off	None
Unidentified Dolphin/Porpoise	Y	3	23-Jul	7:49:00	52.742	175.214	1007	1007	SP	PO	3	>1000	OT	Off	None
Unidentified Dolphin/Porpoise	Y	25	24-Jul	18:48:34	53.467	171.053	1264	315	SP	SW	3	>1000	TR	Off	None
Unidentified Whale	N	1	25-Jul	3:49:10	53.123	172.227	571	571	SA	SW	3	>1000	TR	Off	None
Unidentified Dolphin/Porpoise	N	9	25-Jul	16:42:23	53.074	173.597	469	469	PE	SA	2	>1000	TR	Off	None
Unidentified Dolphin/Porpoise	N	5	25-Jul	17:50:28	53.095	173.679	415	415	SP	SA	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	20:14:31	52.807	174.168	850	850	NO	LG	3	>1000	TR	Off	None
Sperm Whale	N	1	25-Jul	21:11:14	52.737	174.485	1582	1582	SP	DI	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	21:27:57	52.717	174.577	1264	1264	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	21:47:37	52.693	174.684	3369	3369	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	22:04:10	52.673	174.774	2137	2137	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	2	25-Jul	22:15:40	52.660	174.829	3190	3190	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	22:21:18	52.653	174.855	3958	3958	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	22:34:30	52.639	174.916	2645	2645	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	3	25-Jul	22:44:22	52.628	174.961	3958	3958	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	22:56:26	52.615	175.015	5347	5347	MI	BL	1	>1000	TR	Off	None
Sperm Whale	Y	1	25-Jul	23:39:12	52.582	175.148	3928	3928	MI	BL	1	>1000	DP	Off	None
Sperm Whale	Y	1	25-Jul	23:45:28	52.581	175.153	5347	5347	MI	BL	1	>1000	DP	Off	None
Sperm Whale	N	1	25-Jul	23:49:10	52.580	175.155	2285	2285	NO	LG	1	>1000	DP	Off	None
Sperm Whale	Y	1	25-Jul	23:56:40	52.579	175.161	3111	3111	MI	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	0:29:57	52.569	175.200	3958	3958	PE	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	0:45:27	52.561	175.236	5376	5376	SA	BL	1	>1000	LS	On	None

TABLE F.3. Continued.

Species	Useable (Y) or Non-Useable (N)[a]	Group Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (- =°W + =°E)	Initial Sighting Distance from GI Gun (m)	CPA[b] Distance from GI Gun (m)	Initial Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)	Vessel Activity[f]	Gun On or Off[g]	Mitigation Done[h]
Sperm Whale	N	1	26-Jul	0:56:26	52.553	175.268	7182	7182	MI	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	1:08:11	52.544	175.302	3151	3151	NO	LG	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	1:11:00	52.542	175.311	634	634	SA	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	1:12:59	52.541	175.316	1728	1728	UN	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	1:30:11	52.529	175.366	2770	2770	UN	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	1:39:31	52.522	175.391	2730	2730	SP	BL	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	2:01:10	52.509	175.445	2044	2044	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	2	26-Jul	2:01:10	52.509	175.445	5376	5376	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	2:22:41	52.496	175.499	4115	4115	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	2:25:16	52.494	175.506	1688	1688	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	2:36:58	52.487	175.535	4075	4075	UN	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	2:36:58	52.487	175.535	4035	4035	UN	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	3:03:01	52.470	175.601	2730	2730	UN	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	3:03:01	52.470	175.601	1728	1728	NO	LG	1	100-1000	LS	On	None
Unidentified Dolphin/Porpoise	Y	5	26-Jul	3:07:21	52.467	175.613	2730	2730	SA	PO	1	100-1000	LS	On	None
Unidentified Dolphin/Porpoise	Y	15	26-Jul	3:14:33	52.462	175.632	3958	445	ST	PO	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	3:37:40	52.438	175.651	2799	2799	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	2	26-Jul	3:48:19	52.438	175.614	5347	5347	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	4:20:47	52.466	175.501	5376	5376	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:13:24	52.509	175.326	5347	5347	NO	LG	1	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:25:43	52.520	175.284	2799	2799	PE	SW	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:30:15	52.524	175.268	3928	3928	NO	LG	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:38:00	52.530	175.241	1320	430	NO	LG	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:48:30	52.538	175.207	292	292	NO	LG	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	5:58:39	52.547	175.174	1296	1296	SA	SW	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	6:14:23	52.559	175.124	2799	2799	NO	LG	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	6:42:43	52.581	175.035	4075	4075	SP	SW	1	>1000	LS	On	None
Sperm Whale	Y	1	26-Jul	7:12:18	52.603	174.944	1045	1045	UN	FL	3	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	7:44:05	52.628	174.841	1296	1296	PE	BL	3	100-1000	LS	On	None
Sperm Whale	Y	1	26-Jul	7:55:42	52.637	174.803	839	839	SP	BL	3	100-1000	LS	On	None
Unidentified Dolphin/Porpoise	N	3	26-Jul	8:20:02	52.625	174.747	644	644	SA	SW	3	100-1000	LS	On	None
Unidentified Dolphin/Porpoise	N	5	26-Jul	17:36:51	52.603	174.772	408	408	SP	PO	2	100-1000	TR	Off	None
Dall's Porpoise	N	5	31-Jul	7:20:26	52.298	176.711	564	118	SP	PO	5	100-1000	RC	Off	None
Dall's Porpoise	N	5	31-Jul	19:31:00	52.227	176.571	196	75	ST	PO	4	>1000	DP	Off	None
Sperm Whale	N	1	31-Jul	23:06:34	52.298	176.605	3378	3378	UN	BL	4	100-1000	MI	Off	None
Unidentified Dolphin/Porpoise	Y	5	1-Aug	1:56:41	52.262	176.751	876	876	ST	PO	3	>1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	6:45:00	52.143	176.693	1688	1688	NO	MI	3	>1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	7:03:00	52.155	176.614	1556	1556	SP	BL	3	>1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	7:16:23	52.164	176.556	910	910	SP	SW	3	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	7:20:33	52.166	176.538	1591	1591	UN	SW	2	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	7:22:57	52.168	176.527	3378	3378	UN	SW	2	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	7:32:31	52.176	176.484	1239	1239	SA	SW	2	100-1000	TR	Off	None

TABLE F.3. Continued.

Species	Useable (Y) or Non-Useable (N)[a]	Group Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (- =°W + =°E)	Initial Sighting Distance from GI Gun (m)	CPA[b] Distance from GI Gun (m)	Initial Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)	Vessel Activity[f]	Gun On or Off[g]	Mitigation Done[h]
Sperm Whale	Y	1	1-Aug	7:40:25	52.184	176.449	216	216	SP	SW	2	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	17:03:51	52.305	176.485	1035	1035	NO	LG	2	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	17:25:28	52.339	176.474	1767	1767	NO	FD	2	100-1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	17:37:21	52.364	176.462	2730	2730	NO	FL	2	>1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	17:37:21	52.364	176.462	1728	1728	NO	LG	2	>1000	TR	Off	None
Sperm Whale	Y	1	1-Aug	17:37:45	52.364	176.464	1728	1728	NO	LG	2	>1000	TR	Off	None
Sperm Whale	N	1	1-Aug	18:47:05	52.278	176.390	2799	2799	NO	LG	2	100-1000	MI	Off	None
Sperm Whale	N	1	2-Aug	3:03:56	52.371	176.359	2799	2799	NO	LG	2	100-1000	TR	Off	None
Dall's Porpoise	N	7	3-Aug	0:27:24	52.408	176.368	167	167	ST	PO	4	>1000	TR	Off	None
Unidentified Dolphin/Porpoise	Y	1	3-Aug	17:55:57	51.837	176.916	566	566	UN	PO	2	>1000	TR	Off	None
Sperm Whale	Y	1	3-Aug	18:44:45	51.923	177.085	1688	1688	NO	BL	2	>1000	TR	Off	None
Unidentified Whale	Y	1	3-Aug	19:15:00	51.926	177.170	250	250	UN	UN	2	>1000	TR	Off	None
Harbor Porpoise	Y	1	3-Aug	20:13:35	51.814	176.992	571	571	PE	LG	2	100-1000	TR	Off	None
Minke Whale	Y	1	3-Aug	22:45:13	51.730	176.809	429	429	PE	SW	1	>1000	TR	Off	None
Dall's Porpoise	N	8	4-Aug	19:11:00	52.322	177.466	166	166	ST	PO	6	>1000	TR	Off	None
Dall's Porpoise	N	7	5-Aug	0:57:50	52.368	177.493	202	30	ST	PO	6	>1000	LS	On	SZ
Dall's Porpoise	N	5	5-Aug	1:56:18	52.277	177.528	15	15	PE	PO	7	>1000	TR	Off	None
Dall's Porpoise	N	7	5-Aug	23:02:42	52.081	178.661	97	97	PE	PO	6	100-1000	TR	Off	None
Dall's Porpoise	N	2	6-Aug	17:55:27	52.161	178.931	15	15	PE	PO	3	100-1000	RC	Off	None
Unidentified Dolphin/Porpoise	N	15	6-Aug	18:42:28	52.117	178.828	1063	1063	MI	FE	3	100-1000	TR	Off	None
Dall's Porpoise	N	3	7-Aug	4:36:10	51.992	178.850	84	84	PE	PO	3	100-1000	TR	Off	None
Dall's Porpoise	N	9	8-Aug	4:51:10	52.250	178.858	838	838	ST	SW	3	>1000	TR	Off	None
Dall's Porpoise	N	5	8-Aug	6:19:30	52.047	179.110	99	77	ST	PO	3	100-1000	DP	Off	None
Sperm Whale	N	1	9-Aug	17:34:10	51.420	179.720	850	850	NO	LG	3	>1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	17:53:32	51.467	179.700	1239	1239	NO	LG	3	100-1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	18:01:20	51.454	179.686	3369	3369	UN	BL	4	100-1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	18:07:30	51.437	179.689	2137	2137	NO	LG	4	>1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	18:23:19	51.396	179.694	3342	3342	UN	BL	4	>1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	19:15:00	51.388	179.747	3037	3037	UN	BL	3	>1000	TR	Off	None
Sperm Whale	Y	1	9-Aug	19:51:00	51.512	179.807	3342	3342	UN	BL	3	100-1000	TR	Off	None
Dall's Porpoise	Y	5	10-Aug	6:42:20	51.652	179.849	1296	1296	SP	PO	1	100-1000	TR	Off	None
Sperm Whale	N	2	10-Aug	17:36:50	51.665	-179.422	1138	1138	NO	LG	3	>1000	TR	Off	None
Dall's Porpoise	N	4	10-Aug	18:09:05	51.642	-179.546	490	490	SP	PO	3	100-1000	TR	Off	None
Sperm Whale	N	1	10-Aug	19:03:00	51.654	-179.766	440	440	NO	LG	4	>1000	TR	Off	None
Dall's Porpoise	N	2	11-Aug	21:19:07	51.737	-179.620	118	118	PE	PO	4	>1000	MI	Off	None
Sperm Whale	N	1	12-Aug	3:58:22	51.738	-179.295	776	776	SA	BL	4	100-1000	TR	Off	None
Unidentified Mysticete Whale	Y	1	14-Aug	2:09:22	52.047	-176.844	1070	1070	PE	SW	2	>1000	TR	Off	None
Harbor Porpoise	Y	8	14-Aug	2:37:59	52.075	-176.693	660	660	SA	PO	1	>1000	TR	Off	None
Harbor Porpoise	Y	6	14-Aug	2:37:59	52.075	-176.693	660	660	SA	PO	1	>1000	TR	Off	None
Unidentified Dolphin/Porpoise	Y	2	14-Aug	3:23:20	52.117	-176.461	471	471	SP	PO	1	>1000	TR	Off	None
Killer Whale	Y	11	14-Aug	4:05:40	52.156	-176.244	1070	1070	SP	SW	1	>1000	TR	Off	None
Killer Whale	Y	1	14-Aug	7:21:00	52.247	-175.129	1264	604	MI	SW	1	100-1000	TR	Off	None
Dall's Porpoise	N	13	14-Aug	20:43:50	52.465	-173.691	1065	1065	ST	PO	3	100-1000	TR	Off	None

TABLE F.3. Continued.

Species	Useable (Y) or Non-Useable (N)[a]	Group Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (- =°W + =°E)	Initial Sighting Distance from GI Gun (m)	CPA[b] Distance from GI Gun (m)	Initial Movement[c]	Initial Behavior[d]	Bf[e]	Water Depth (m)	Vessel Activity[f]	Gun On or Off[g]	Mitigation Done[h]
Dall's Porpoise	N	4	14-Aug	21:13:19	52.480	-173.542	1264	1264	ST	PO	3	100-1000	TR	Off	None
Dall's Porpoise	N	2	14-Aug	21:47:36	52.540	-173.397	522	522	ST	PO	3	100-1000	TR	Off	None
Dall's Porpoise	N	2	15-Aug	0:23:52	52.683	-172.660	1757	1757	PE	PO	3	>1000	TR	Off	None
Sperm Whale	N	1	15-Aug	5:20:59	52.615	-172.706	1239	1239	MI	LG	3	100-1000	TR	Off	None
Dall's Porpoise	N	4	15-Aug	6:06:00	52.629	-172.815	194	194	MI	PO	3	100-1000	DP	Off	None
Killer Whale	Y	2	15-Aug	17:25:45	52.668	-171.985	4876	838	PE	SW	3	100-1000	TR	Off	None
Minke Whale	Y	1	15-Aug	19:18:00	52.664	-171.748	77	77	PE	SW	2	100-1000	TR	Off	None
Sperm Whale	Y	1	15-Aug	20:46:59	52.627	-172.104	3888	3888	NO	LG	3	100-1000	TR	Off	None
Unidentified Whale	N	1	17-Aug	2:31:58	52.399	-172.151	150	150	ST	SW	2	100-1000	MI	Off	None
Northern Fur Seal	N	3	18-Aug	23:55:40	52.968	-169.407	110	110	SA	SW	2	100-1000	TR	Off	None
Northern Fur Seal	Y	2	19-Aug	0:49:52	52.965	-169.471	110	110	MI	SW	2	100-1000	TR	Off	None
Unidentified Dolphin/Porpoise	Y	2	19-Aug	5:07:28	52.976	-169.315	1007	1007	SP	PO	2	100-1000	TR	Off	None
Northern Fur Seal	N	2	20-Aug	1:19:00	53.538	-168.688	202	202	NO	LO	2	>1000	TR	Off	None
Northern Fur Seal	Y	1	20-Aug	1:49:42	53.591	-168.609	250	250	NO	LG	2	>1000	TR	Off	None
Humpback Whale	N	1	20-Aug	16:07:36	54.042	-166.816	364	364	SA	BL	2	100-1000	TR	Off	None
Northern Fur Seal	N	1	20-Aug	16:12:59	54.041	-166.838	150	150	SP	LO	2	100-1000	TR	Off	None
Humpback Whale	N	3	20-Aug	17:07:18	54.037	-167.055	2111	2111	SP	SW	2	100-1000	TR	Off	None
Humpback Whale	N	2	20-Aug	17:13:28	54.037	-167.078	2075	2075	SP	SW	2	>1000	TR	Off	None
Unidentified Whale	N	1	20-Aug	17:18:44	54.031	-167.096	1582	1582	UN	BL	2	>1000	TR	Off	None
Humpback Whale	N	2	20-Aug	17:31:05	54.017	-167.138	1264	1264	SA	SW	2	>1000	TR	Off	None
Humpback Whale	Y	2	20-Aug	20:47:46	53.965	-167.244	1127	1127	SP	SW	3	100-1000	TR	Off	None
Killer Whale	Y	5	20-Aug	20:47:46	53.965	-167.244	1127	1127	SP	SW	3	100-1000	TR	Off	None
Humpback Whale	N	1	20-Aug	20:55:07	53.966	-167.246	2063	2063	UN	BL	3	100-1000	MI	Off	None
Humpback Whale	N	2	20-Aug	21:03:10	53.966	-167.246	4036	4036	SP	BL	3	100-1000	MI	Off	None
Unidentified Whale	N	1	20-Aug	21:25:53	53.965	-167.245	4927	4927	UN	BL	3	100-1000	MI	Off	None

[a] Y=Visual sightings made during daylight periods both within the survey area and during transit to and from the area, N=periods 90 s to 2 h after the GI gun was turned off (post-seismic), night-time observations, poor visibility conditions (visibility <3.5 km), and periods with Beaufort Wind Force (Bf) >5 (>2 for porpoises). Also excluded were periods when the *Thompson's* speed was <3.7 km/h (2 kt) or with >1 radian of severe glare between 90º left and 90º right of the bow.

[b] CPA is the distance at the closest observed point of approach to the GI gun; this is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

[c] The initial movement of the individual or group relative to the vessel; MI=milling, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, UN=unknown, NO=no moment relative to vessel.

[d] The initial behavior observed; BL=blowing, BR=breaching, DI=diving, FD=front dive, FE=feeding, FL=fluking, LG=logging, LO=looking, PO=porpoising, SA=surface active, SW=swimming, TR=traveling, UN=unknown.

[e] Beaufort Wind Force scale.

[f] Activity of the vessel at the time of the sighting; LS=operating GI gun on a seismic survey line and collecting geophysical data, OT=other (a period of no seismic activity, SH=operating GI gun offline usually during turns between seismic lines, SZ=sound radius shut down, TR=traveling at speeds of >2 kt, DP=deploying rock dredge, RC=recovering rock dredge, MI=Miscellaneous (traveling at speeds <2 kt).

[g] The GI gun operated at a volume of 105 in^3.

[h] Mitigating measures; SZ= safety zone shut down.

APPENDIX G:
MARINE MAMMAL DENSITY AND EXPOSURE ESTIMATES

TABLE G.1. Sightings and densities of marine mammals during non-seismic periods in water depths 100–1000 m near the Aleutian Islands during ship surveys, 20 July–20 August 2005. Non-seismic periods are periods before seismic started or periods >2 h after seismic ended. Survey effort was 617 km during Beaufort Wind Force (Bf) ≤ 5 and 151 km with Bf ≤ 2. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings[c]	Mean group size	Average density[a] corrected for *f*(0) and *g*(0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Unidentified dolphin	0	—	0.00	—
Killer whale	3	10.1	10.10	0.76
Phocoenidae				
Dall's porpoise	1	5.00	8.58	0.94
Total Delphinidae & Dall's Porpoise	**4**		**18.68**	**0.72**
Harbor porpoise	1	1.00	1.72	0.94
Unidentified dolphin/porpoise	2	5.00	17.17	0.83
Physeteridae				
Sperm whale	*11*	*1.00*	*7.18*	0.55
Mysticetes				
Humpback whale	*2*	2.50	*3.15*	0.83
Minke whale	1	1.00	0.36	0.94
Fin whale	*0*	—	*0.00*	—
Unidentified mysticete	0	—	0.00	—
Unidentified whale	1	1.00	0.63	0.94
Total Other Cetaceans	**18**		**30.21**	**0.47**
Total Cetaceans	**22**		**48.89**	**0.44**
Pinnipeds				
Northern fur seal	1	2.00	2.53	0.94
Total Pinnipeds	**1**		**2.53**	**0.94**

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

[c] An additional 10 Dall's porpoise, 5 sperm whale, 4 humpback whale, 1 unidentified dolphin/porpoise, 2 unidentified whale and 2 northern fur seal sightings were made during "non-useable" survey conditions.

TABLE G.2. Sightings and densities of marine mammals during non-seismic periods in water depths >1000 m near the Aleutian Islands during ship surveys, 20 July–20 August 2005. Survey effort was 1391 km during Beaufort Wind Force (Bf) ≤ 5 and 364 km with Bf ≤ 2. Otherwise as in Table G.1.

Species	Number of sightings[c]	Mean group size	Average density [a] corrected for $f(0)$ and $g(0)$ (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Unidentified dolphin	0	—	0.00	—
Killer whale	2	6.50	7.28	0.83
Phocoenidae				
Dall's porpoise	0	—	0.00	—
Total Delphinidae & Dall's porpoise	**2**		**7.28**	**0.83**
Harbor porpoise	2	7.00	10.66	0.83
Unidentified porpoise/dolphin	8	7.00	32.59	0.60
Physeteridae				
Sperm whale	*20*	*1.15*	*6.66*	*0.45*
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	3	1.67	0.79	0.76
Fin whale	*2*	2.00	*1.12*	0.83
Unidentified mysticete	7	1.57	3.07	0.62
Unidentified whale	1	1.00	0.28	0.94
Total Other Cetaceans	**43**		**55.17**	0.33
Total Cetaceans	**45**		**62.45**	0.32
Pinnipeds				
Northern fur seal	1	1.00	0.56	0.94
Total Pinnipeds	**1**		**0.56**	**0.94**

[a] Values for $f(0)$ and $g(0)$ are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

[c] An additional 6 Dall's porpoise, 5 sperm whale, 2 humpback whale, 1 minke whale, 2 unidentified dolphin/porpoise, 2 unidentified whale and 1 northern fur seal sightings were made during "non-useable" survey conditions.

TABLE G.3. Sightings and densities of marine mammals during seismic periods in water depths 100–1000 m near the Aleutian Islands during ship surveys, 23 July–7 August 2005. Survey effort was 52 km during Beaufort Wind Force (Bf) ≤ 5 and 38 km with Bf ≤ 2. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings[c]	Mean group size	Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Unidentified dolphin	0	—	0.00	—
Killer whale	0	—	0.00	—
Phocoenidae				
Dall's porpoise	0	—	0.00	—
Total Delphinidae & Dall's porpoise	**0**		**0.00**	**—**
Harbor porpoise	0	—	0.00	—
Unidentified porpoise/dolphin	2	10.0	407.40	0.83
Physeteridae				
Sperm whale	*15*	1.13	*131.71*	0.50
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Fin whale	*0*	—	*0.00*	—
Unidentified mysticete	0	—	0.00	—
Unidentified whale	0	—	0.00	—
Total Other Cetaceans	**17**		**539.11**	**0.48**
Total Cetaceans	**17**		**539.11**	**0.48**
Pinnipeds				
Northern fur seal	0	—	0.00	—
Total Pinnipeds	**0**		**0.00**	—

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e$n from Koski et al. (1998), but likely underestimates the true variability.

[c] An additional group of unidentified dolphins/porpoises was made during "non-useable" survey conditions.

TABLE G.4. Sightings and densities of marine mammals during seismic periods in water depths >1000 m near the Aleutian Islands during ship surveys, 23 July–7 August 2005. Survey effort was 59 km during Beaufort Wind Force (Bf) ≤ 5 and 57 km with Bf ≤ 2. Species in italics are listed under the U.S. ESA as endangered.

Species	Number of sightings[c]	Mean group size	Average density [a] corrected for *f*(0) and *g*(0) (# /1000 km^2)	
			Density	CV [b]
Odontocetes				
Delphinidae				
Unidentified dolphin	0	—	0.00	—
Killer whale	0	—	0.00	—
Phocoenidae				
Dall's porpoise	0	—	0.00	—
Total Delphinidae & Dall's porpoise	**0**		**0.00**	—
Harbor porpoise	0	—	0.00	—
Unidentified porpoise/dolphin	0	—	0.00	—
Physeteridae				
Sperm whale	*15*	*1.00*	*102.43*	0.50
Mysticetes				
Humpback whale	*0*	—	*0.00*	—
Minke whale	0	—	0.00	—
Fin whale	*0*	—	*0.00*	—
Unidentified mysticete	0	—	0.00	—
Unidentified whale	0	—	0.00	—
Total Other Cetaceans	**15**		**102.43**	**0.50**
Total Cetaceans	**15**		**102.43**	**0.50**
Pinnipeds				
Northern fur seal	0	—	0.00	—
Total Pinnipeds	**0**	—	**0.00**	—

[a] Values for *f*(0) and *g*(0) are from Koski et al. (1998) and Barlow (1999).

[b] CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation 0.94 - 0.162$\log_e$n from Koski et al. (1998), but likely underestimates the true

[c] Additional single groups of sperm whales and Dall's porpoise were made during "non-useable" survey conditions.

TABLE G.5. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that would have been exposed to seismic sounds ≥160 dB (and ≥170 dB) near the Aleutian Islands during seismic surveys, 23 July–7 August 2005. Based on calculated densities from non-seismic periods (Tables G.1 and G.2). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	**Numbers of exposures** [a]						**Minimum number of individuals** [a]					
Water depth (m)	**100-1000**		**>1000**		**All depths**		**100-1000**		**>1000**		**All depths**	
Area in km^2 ensonified to ≥160 dB (≥170 dB)	151.7	(47.8)	205.1	(66.2)			151.7	(47.8)	203.8	(66.0)		
Odontocetes												
Delphinidae												
Unidentified dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Killer whale	2	(0)	1	(0)	3	(1)	2	(0)	1	(0)	3	(1)
Phocoenidae												
Dall's porpoise	1	(0)	0	(0)	1	(0)	1	(0)	0	(0)	1	(0)
Total Delphinidae & Dall's porpoise	**3**	**(1)**	**1**	**(0)**	**4**	**(1)**	**3**	**(1)**	**1**	**(0)**	**4**	**(1)**
Harbor porpoise	0		2		2		0		2		2	
Unidentified porpoise/dolphin	3		7		9		3		7		9	
Physeteridae												
Sperm whale	1		1		2		1		1		2	
Mysticetes												
Humpback whale	0		0		0		0		0		0	
Minke whale	0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0	
Unidentified mysticete	0		1		1		0		1		1	
Unidentified whale	0		0		0		0		0		0	
Total Other Cetaceans	**4**		**11**		**15**		**4**		**11**		**15**	
Total Cetaceans	**7**		**12**		**19**		**7**		**12**		**19**	
Pinnipeds												
Northern fur seal	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Pinnipeds	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**

[a] Slight apparent discrepancies in totals result from rounding to integers.

TABLE G.6. Estimated numbers of exposures and estimated minimum numbers of individual marine mammals that were exposed to seismic sounds ≥160 dB (and ≥170 dB) near the Aleutian Islands during seismic surveys, 23 July–7 August 2005. Based on calculated densities from seismic periods (Appendix G.3 and G.4). Species in italics are listed under the U.S. ESA as endangered.

Species/species group	Numbers of exposures [a]						Minimum number of individuals [a]					
Water depth (m)	100-1000		>1000		All depths		100-1000		>1000		All depths	
Area in km^2 ensonified to ≥160 dB (≥170 dB)	151.7	(47.8)	205.1	(66.2)			151.7	(47.8)	203.8	(66.0)		
Odontocetes												
Delphinidae												
Unidentified dolphin	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Killer whale	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Phocoenidae												
Dall's porpoise	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Delphinidae & Dall's porpoise	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**
Harbor porpoise	0		0		0		0		0		0	
Unidentified porpoise/dolphin	62		0		62		62		0		62	
Physeteridae												
Sperm whale	20		21		41		20		21		41	
Mysticetes												
Humpback whale	0		0		0		0		0		0	
Minke whale	0		0		0		0		0		0	
Fin whale	0		0		0		0		0		0	
Unidentified mysticete	0		0		0		0		0		0	
Unidentified whale	0		0		0		0		0		0	
Total Other Cetaceans	**82**		**21**		**103**		**82**		**21**		**103**	
Total Cetaceans	**82**		**21**		**103**		**82**		**21**		**103**	
Pinnipeds												
Northern fur seal	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Pinnipeds	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**	**0**	**(0)**

[a] Slight apparent discrepancies in totals result from rounding to integers.